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(12) United States Patent
Messerly et al.

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(54) **SURGICAL SYSTEM COUPLEABLE WITH STAPLE CARTRIDGE AND RADIO FREQUENCY CARTRIDGE, AND HAVING A PLURALITY OF RADIO-FREQUENCY ENERGY RETURN PATHS**

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(73) Assignee: **Cilag GmbH International**, Zug (CH)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 109 days.

(21) Appl. No.: **15/636,134**

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(65) **Prior Publication Data**

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(51) **Int. Cl.**

A61B 17/00 (2006.01)
A61B 18/14 (2006.01)

(Continued)

(52) **U.S. Cl.**

CPC ***A61B 18/1445*** (2013.01); ***A61B 17/07207*** (2013.01); ***A61B 17/29*** (2013.01); ***A61B 18/1442*** (2013.01); *A61B 17/295* (2013.01); *A61B 2017/00026* (2013.01); *A61B 2017/0046* (2013.01); *A61B 2017/00075* (2013.01); *A61B 2017/00115* (2013.01); *A61B 2017/00119* (2013.01); *A61B 2017/00128* (2013.01); *A61B 2017/00353* (2013.01);

(Continued)

(58) **Field of Classification Search**

CPC A61B 18/1445; A61B 18/1442; A61B 17/07207; A61B 17/29; A61B 17/068–07292; A61B 2017/00668; A61B 2018/1495

See application file for complete search history.

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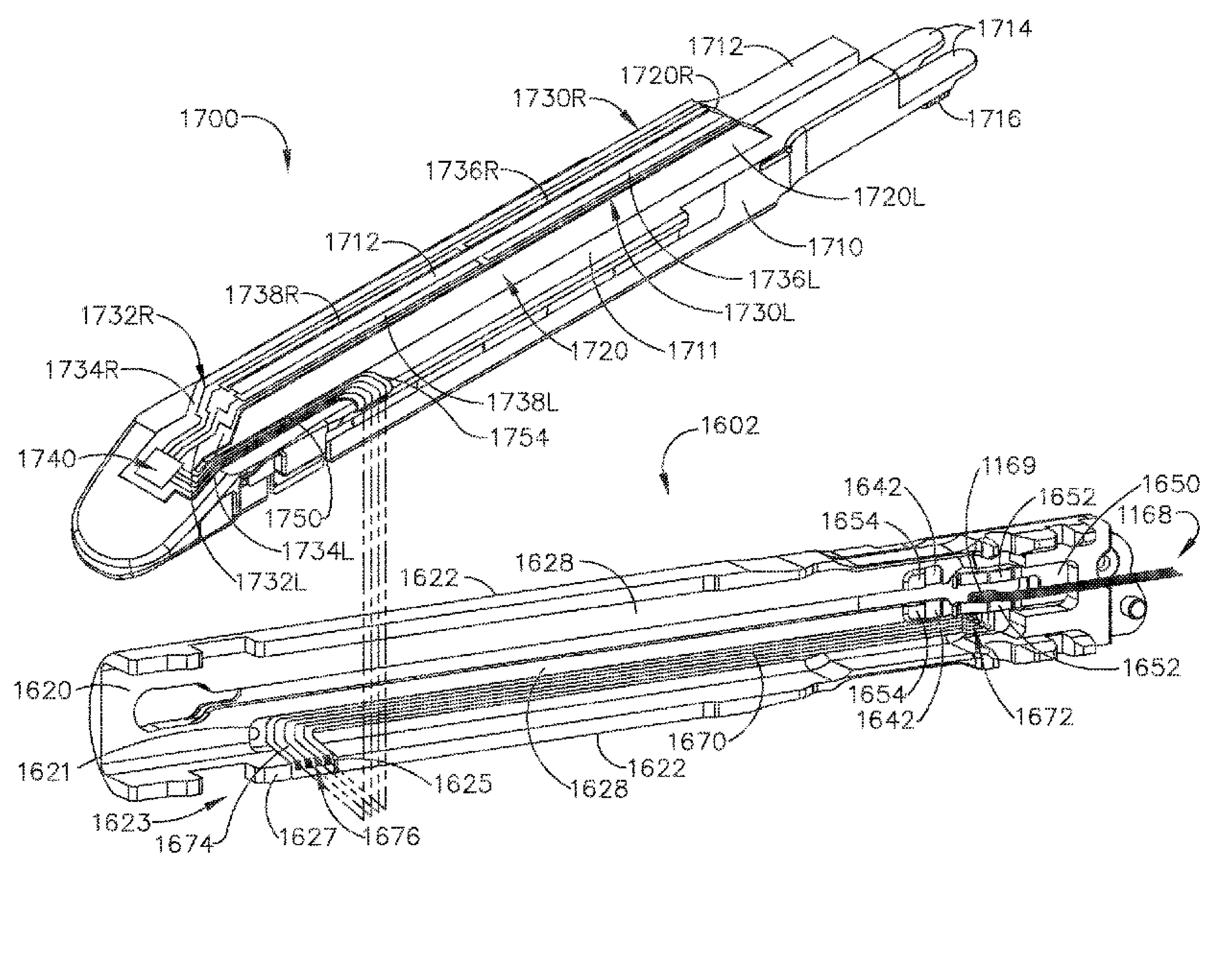
Primary Examiner — Jaymi E Della

(57) **ABSTRACT**

An interchangeable tool assembly is disclosed. The interchangeable tool assembly includes a first jaw configured to support a staple cartridge during a first time period and a radio-frequency cartridge during a second time period. A second jaw is coupled to the first jaw. A surface of the second jaw defines a plurality of staple forming pockets configured to form staples driven from the staple cartridge. An electrically insulative material covers segments of the surface of the second jaw other than the staple forming pockets. The staple forming pockets define at least one return path for radio-frequency energy delivered by the radio-frequency cartridge.

18 Claims, 21 Drawing Sheets



(51) **Int. Cl.**

A61B 17/072	(2006.01)
A61B 17/29	(2006.01)
A61B 90/00	(2016.01)
A61B 18/00	(2006.01)
A61B 17/295	(2006.01)
A61B 18/16	(2006.01)

(52) **U.S. Cl.**

CPC *A61B 2017/00398* (2013.01); *A61B 2017/00464* (2013.01); *A61B 2017/00477* (2013.01); *A61B 2017/00734* (2013.01); *A61B 2017/07257* (2013.01); *A61B 2017/07271* (2013.01); *A61B 2017/07285* (2013.01); *A61B 2017/2902* (2013.01); *A61B 2017/2927* (2013.01); *A61B 2017/2929* (2013.01); *A61B 2018/0063* (2013.01); *A61B 2018/00083* (2013.01); *A61B 2018/00589* (2013.01); *A61B 2018/1455* (2013.01); *A61B 2018/1495* (2013.01); *A61B 2018/162* (2013.01); *A61B 2018/165* (2013.01); *A61B 2090/061* (2016.02); *A61B 2090/065* (2016.02)

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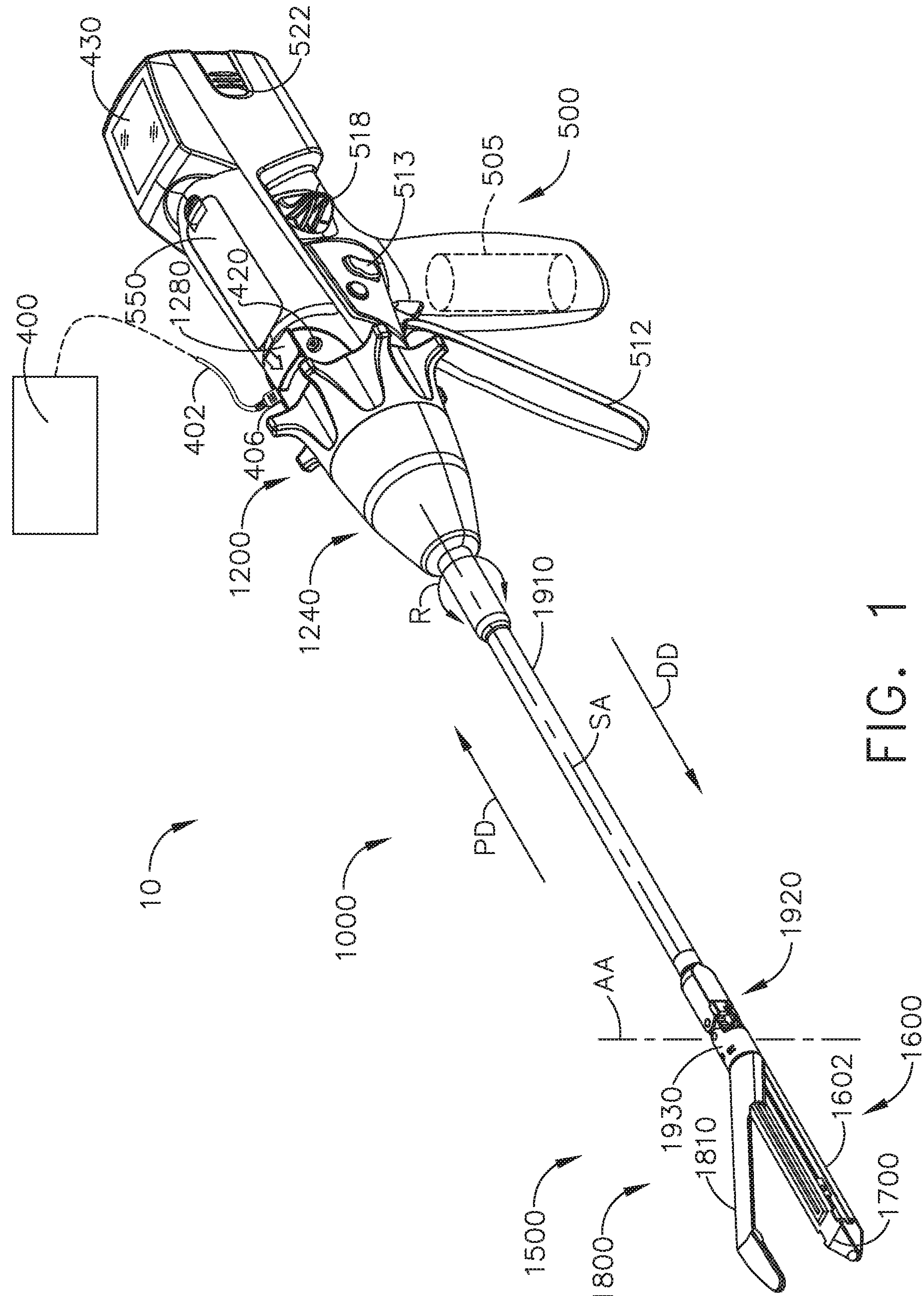
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FIG. 1

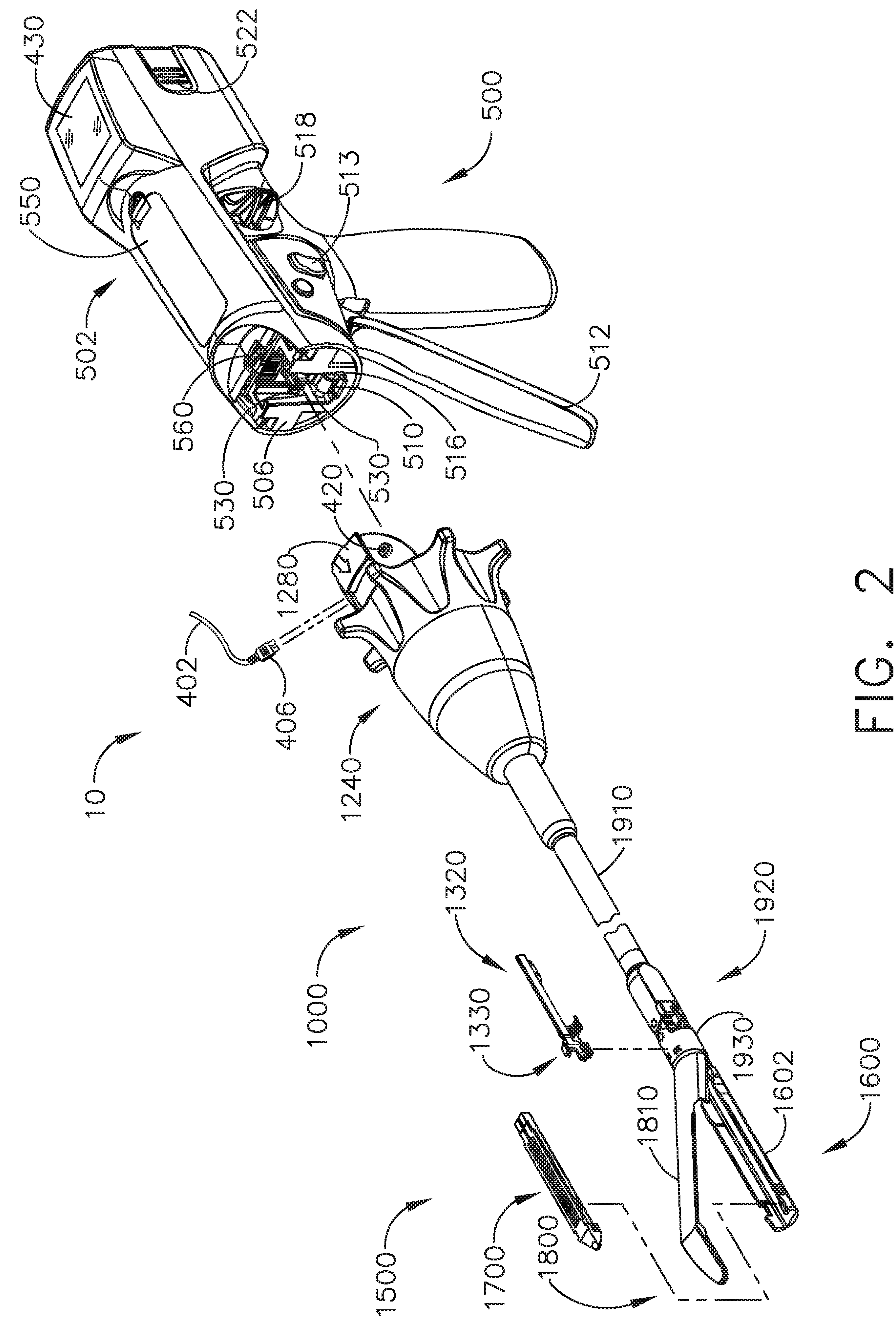
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FIG. 2

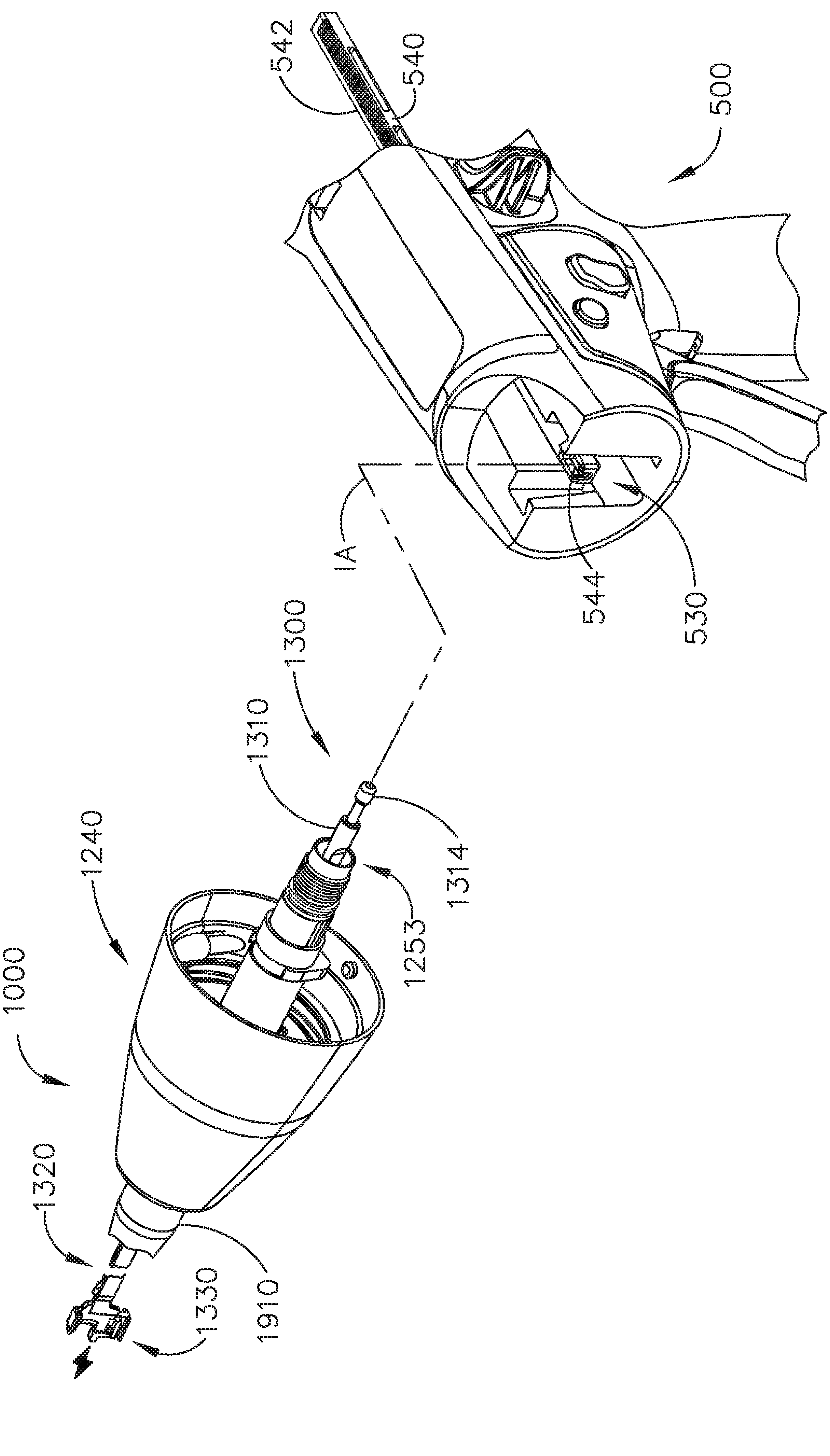
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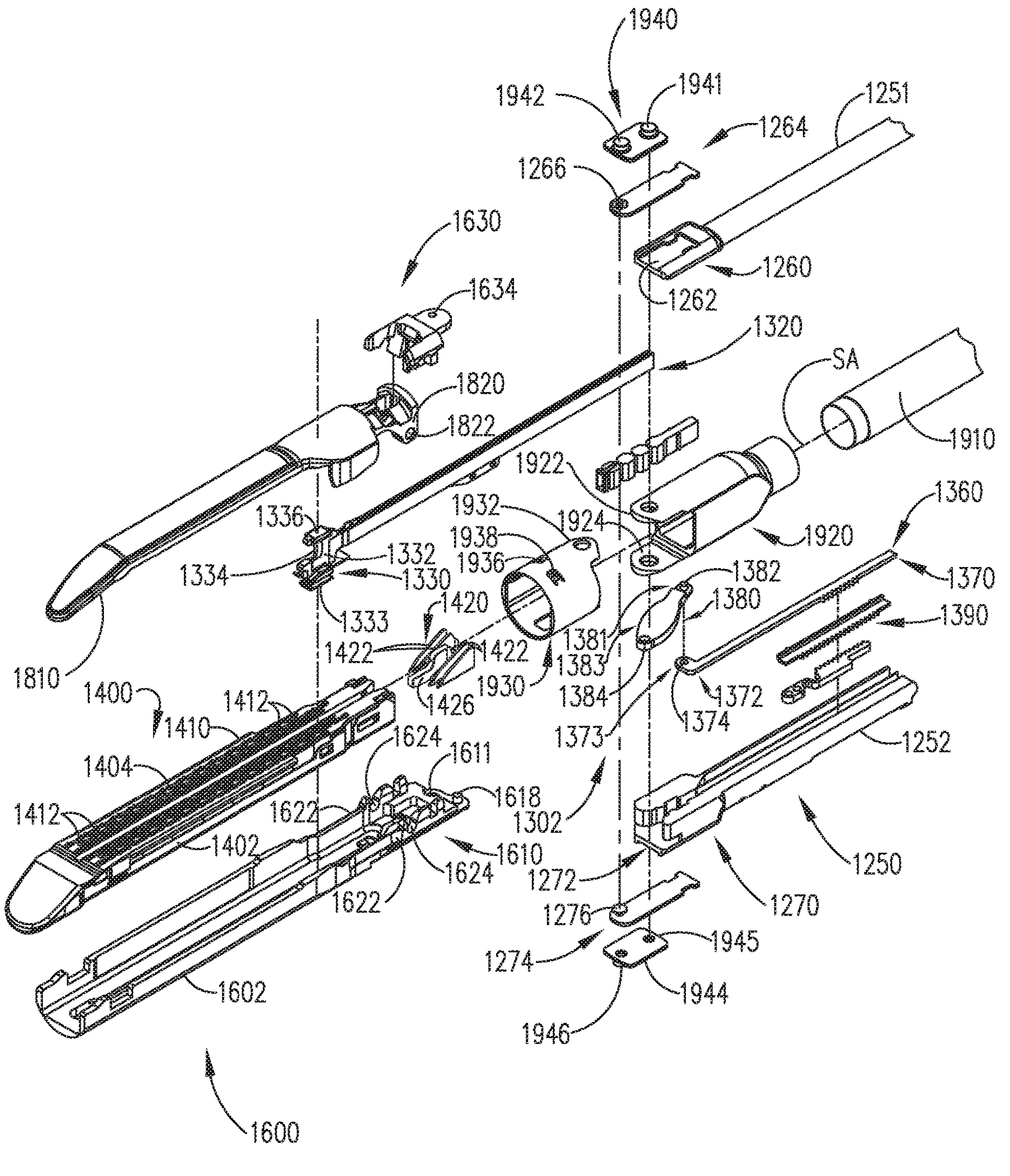
FIG. 3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1938
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1330
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1360
1370
1333
1420
1380
1390
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1422
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1383
1810
1426
1930
1384
1372
1400
1412
1374
1410
1373
1624
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1302
1622
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FIG. 4

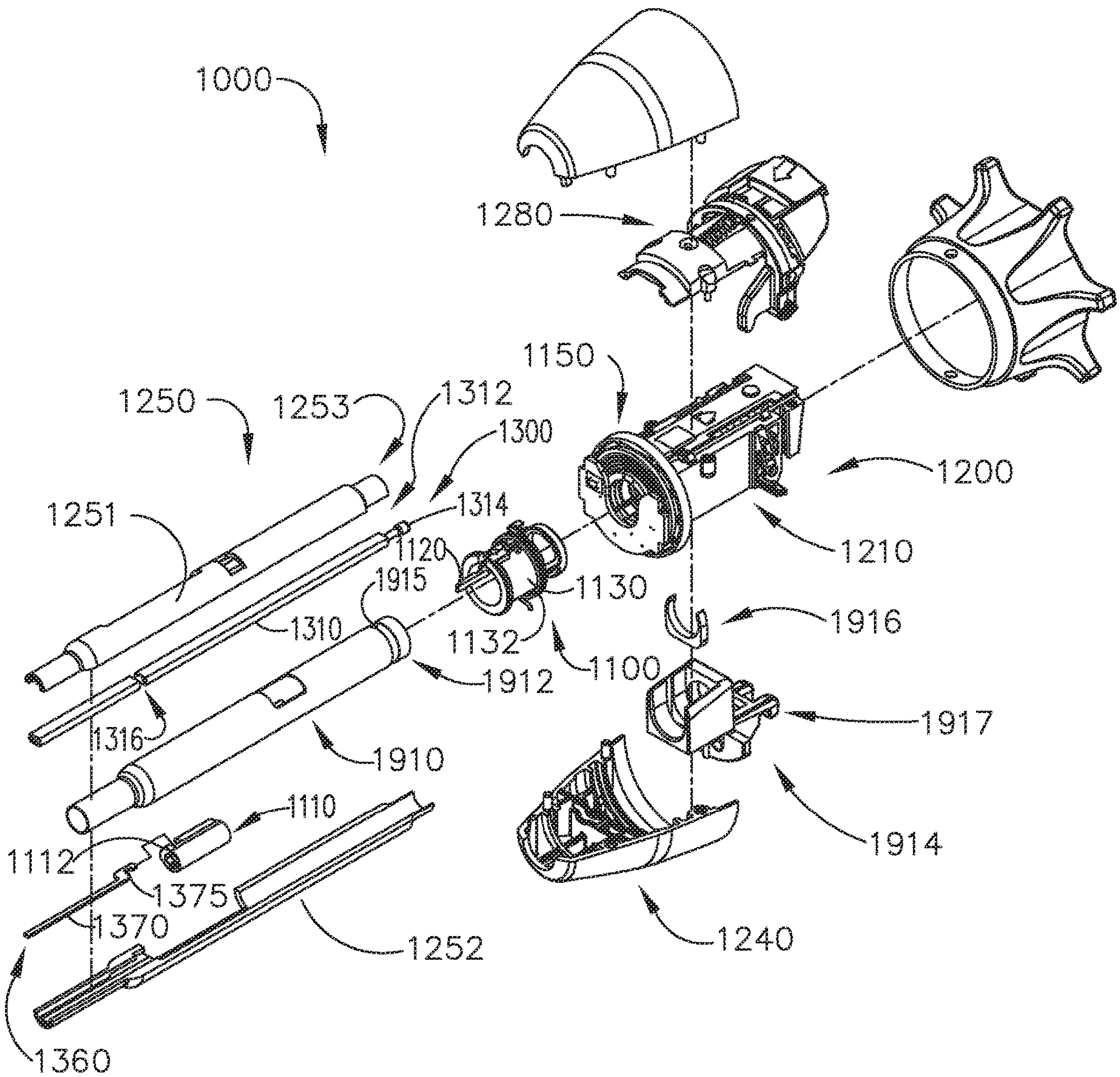
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FIG. 5

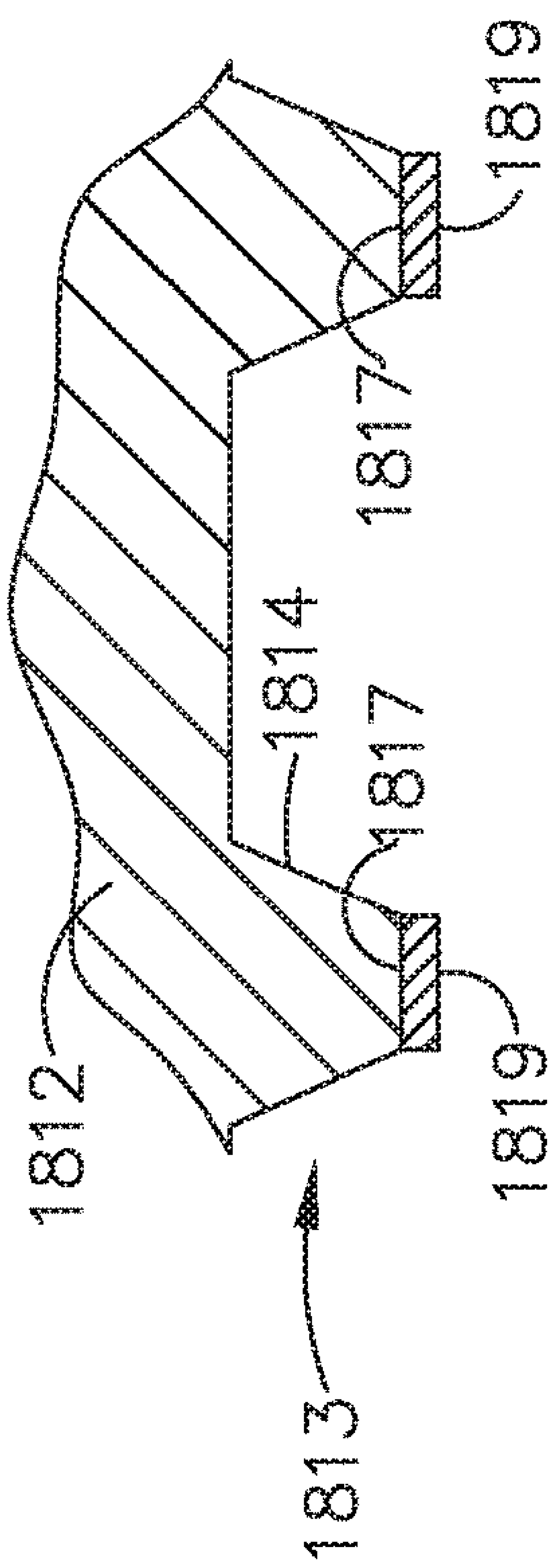
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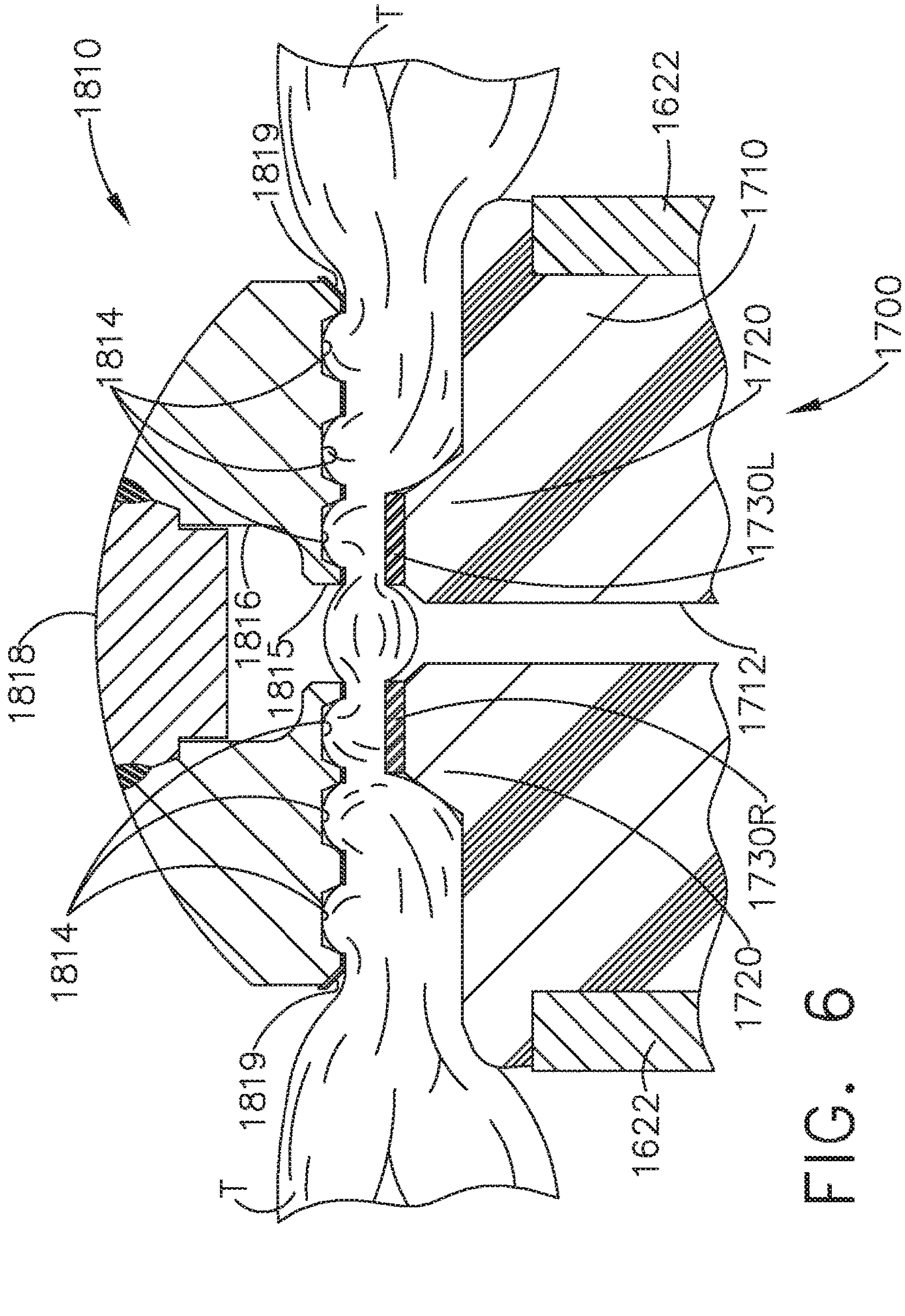
FIG. 7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1622
T

FIG. 6

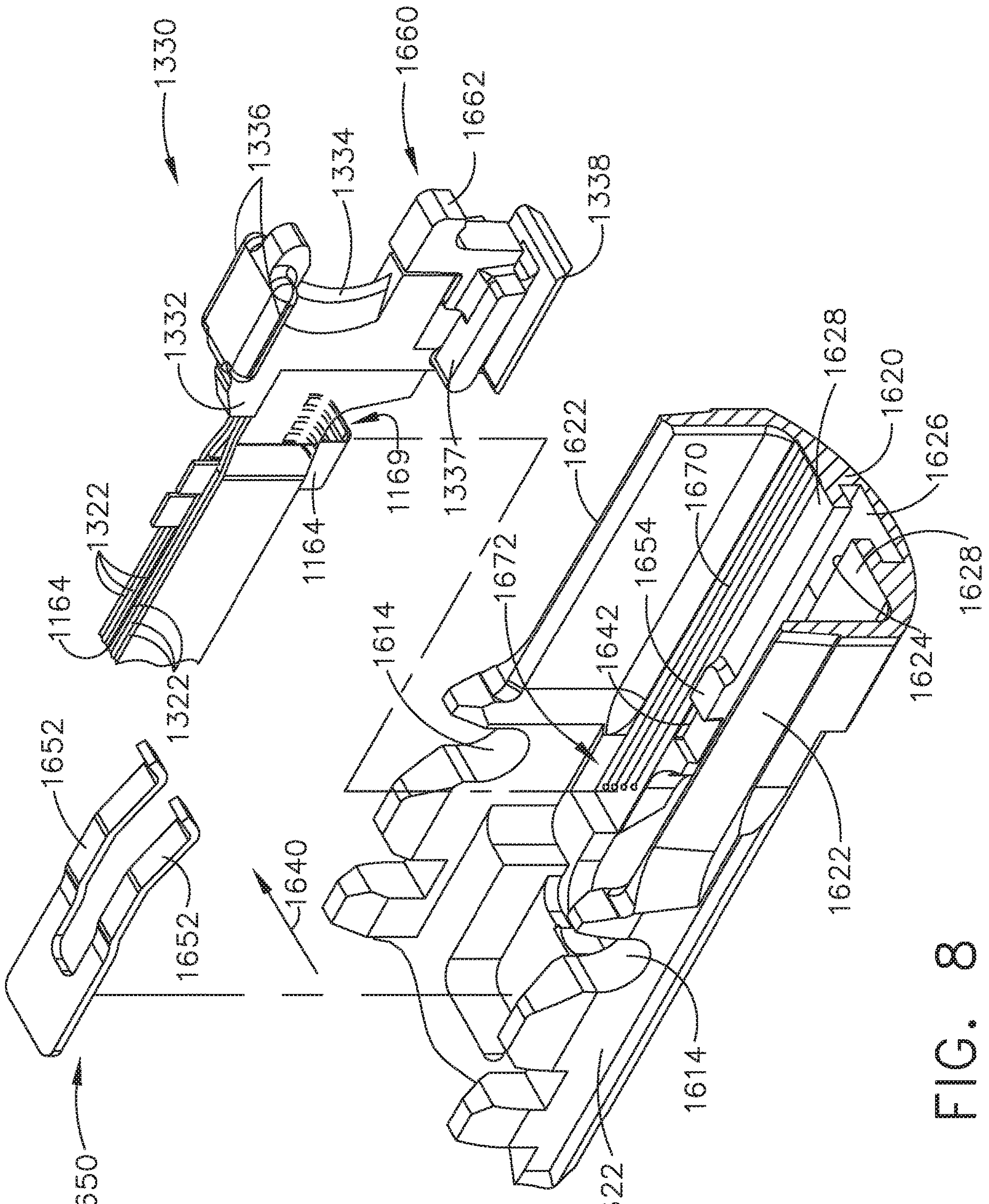
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FIG. 8

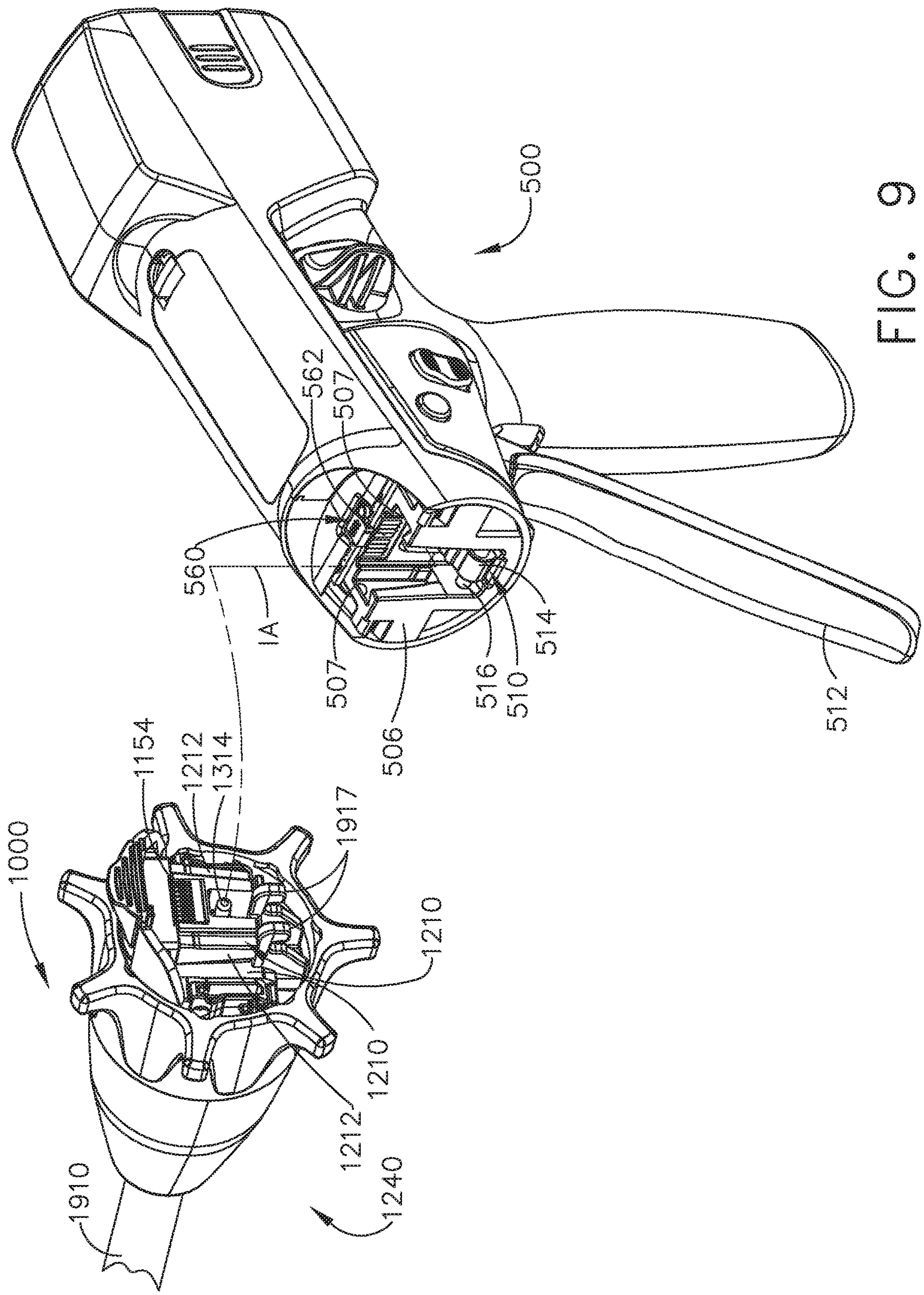
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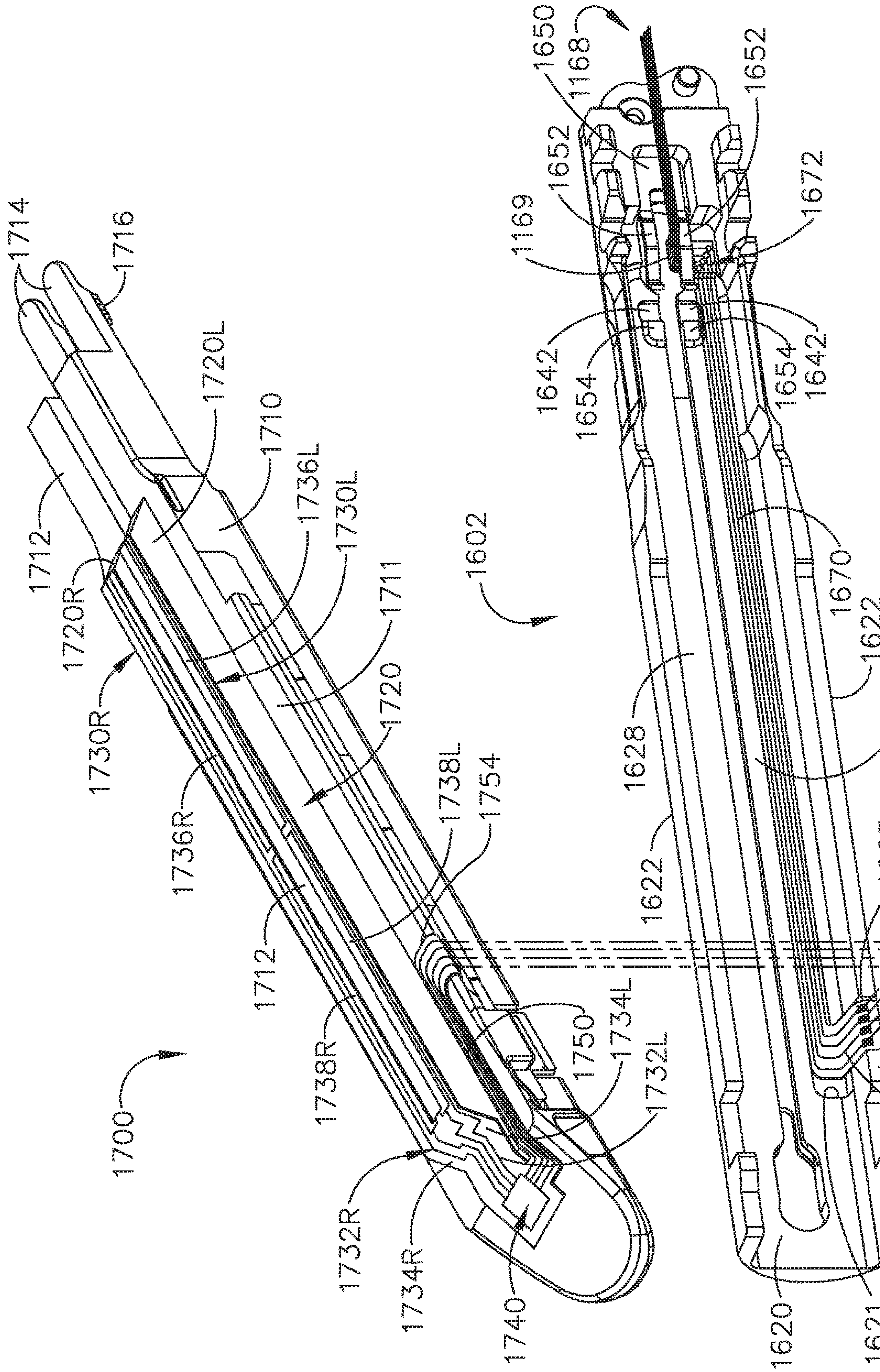
FIG. 9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1712
1738R
1700
1750
1734L
1732L
1732R
1734R
1740
1650
1168
1652
1652
1169
1672
1642
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1654
1642
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FIG. 10

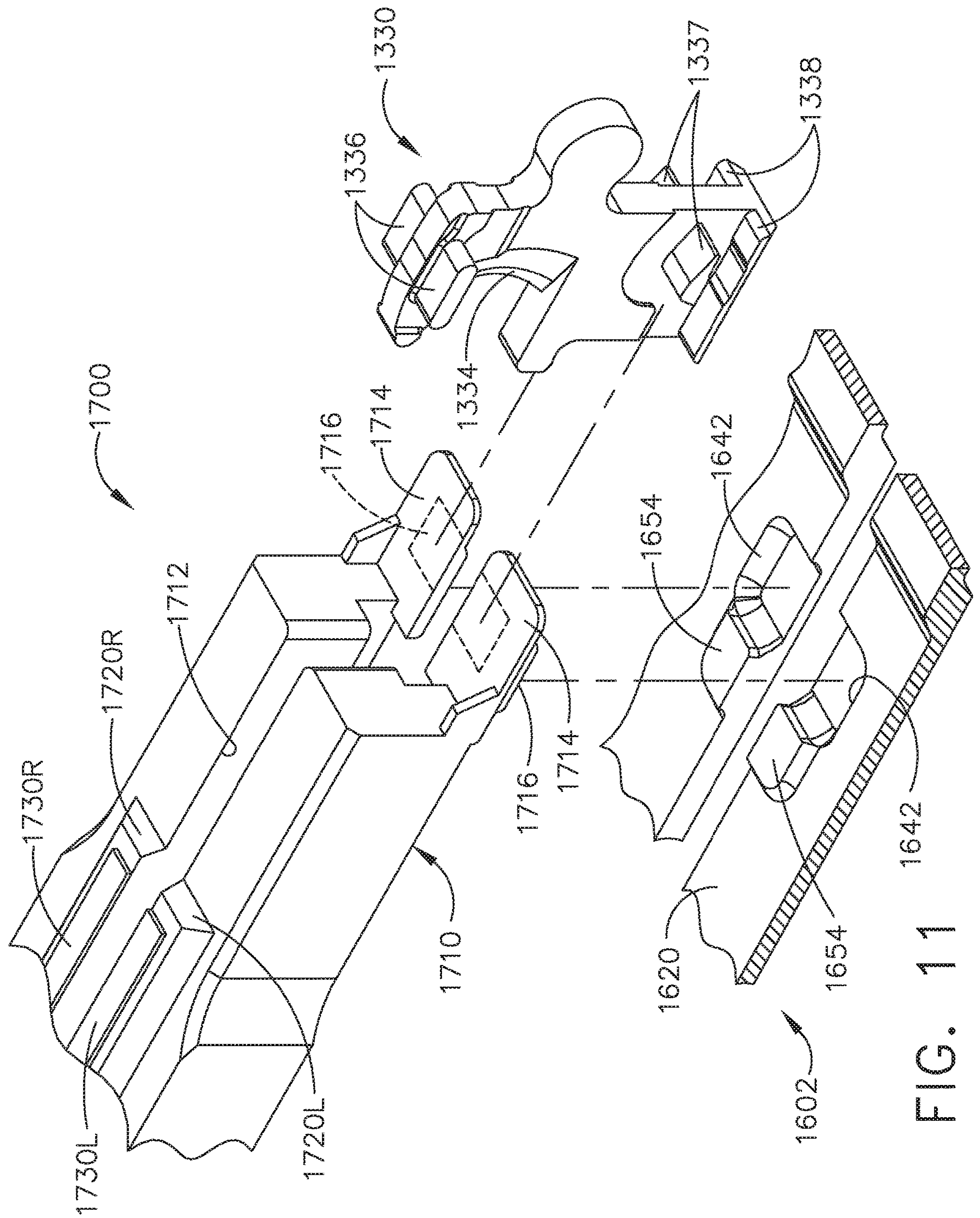
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FIG. 11

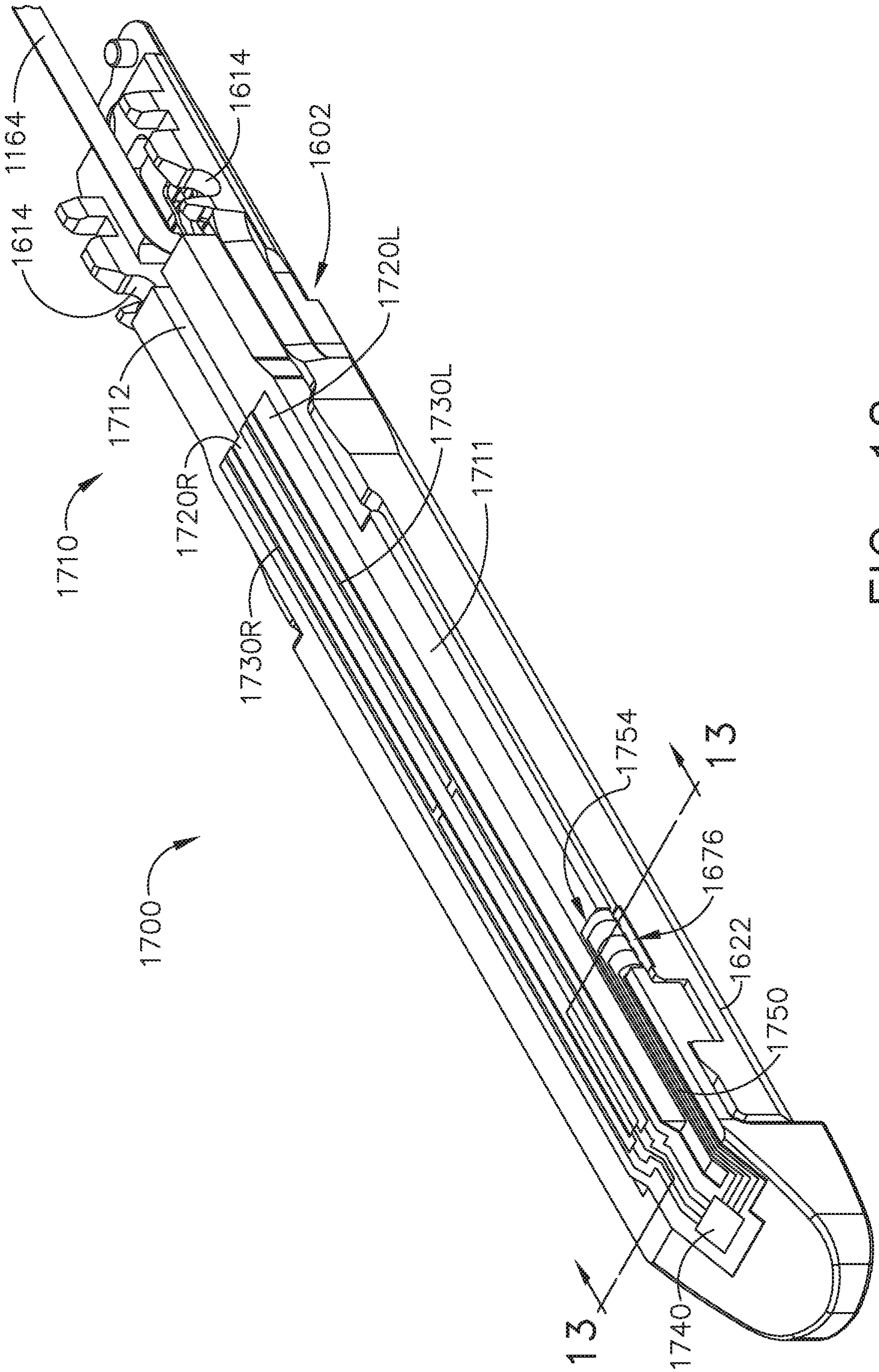
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FIG. 12

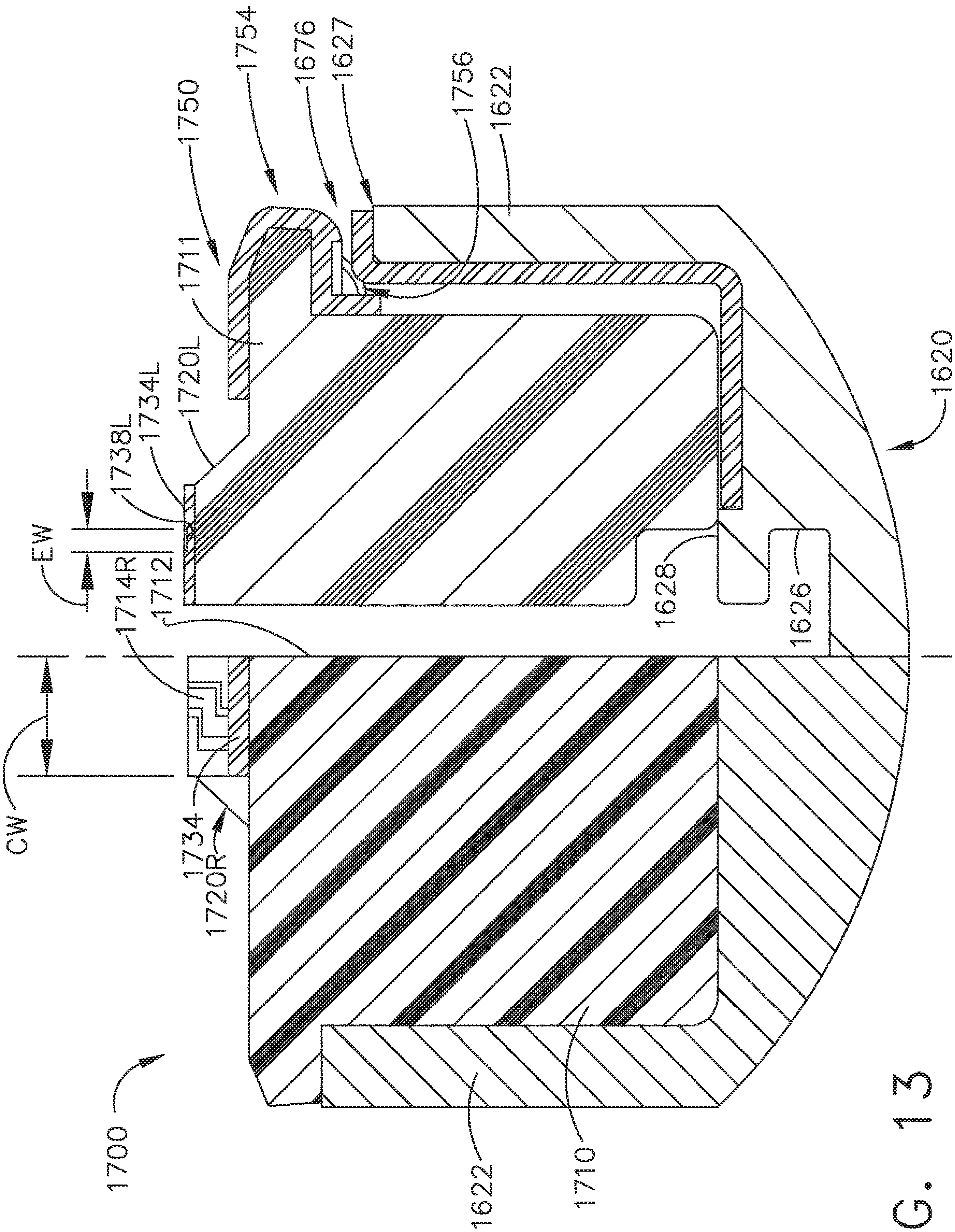
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FIG. 13

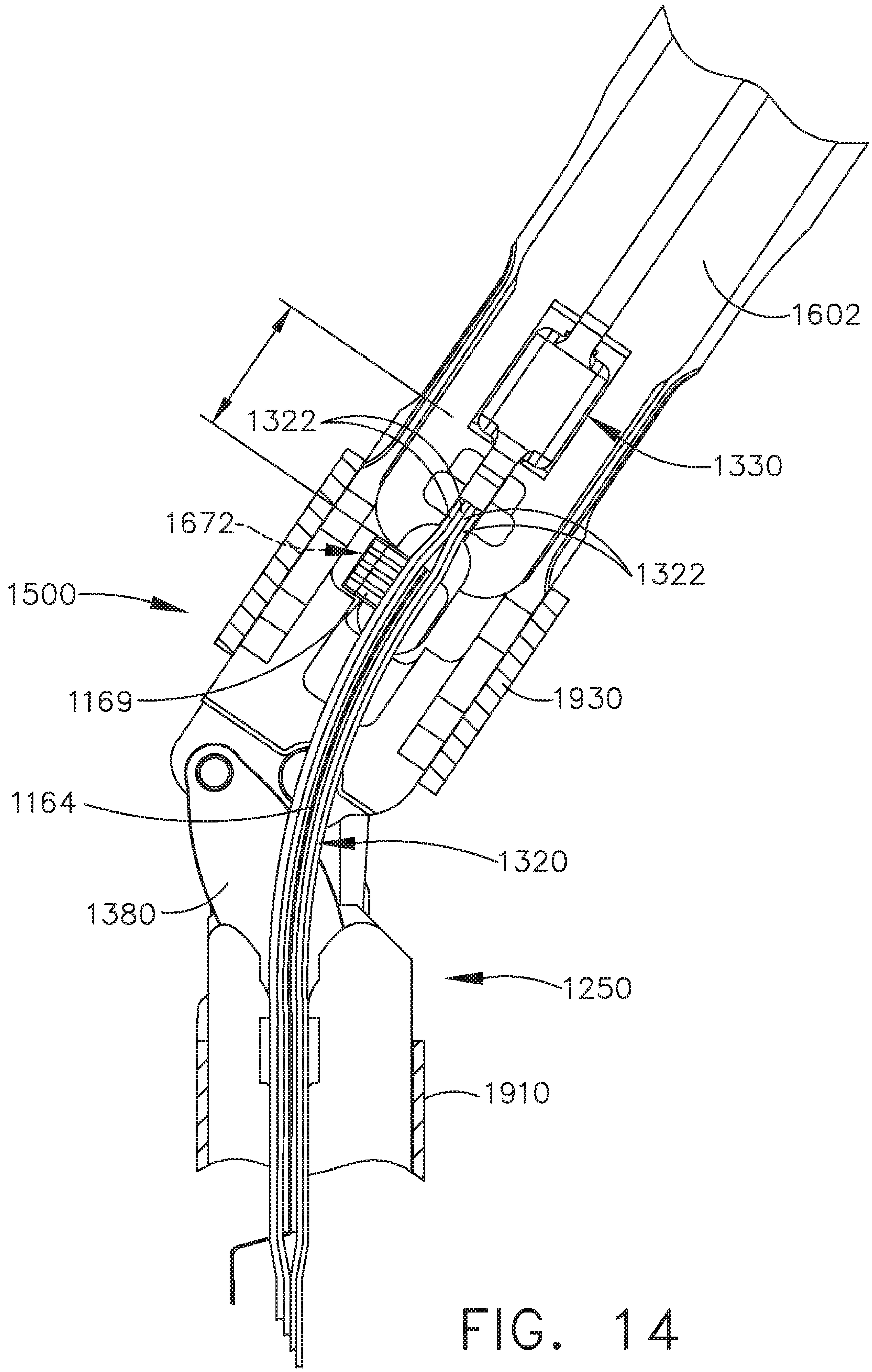
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FIG. 14

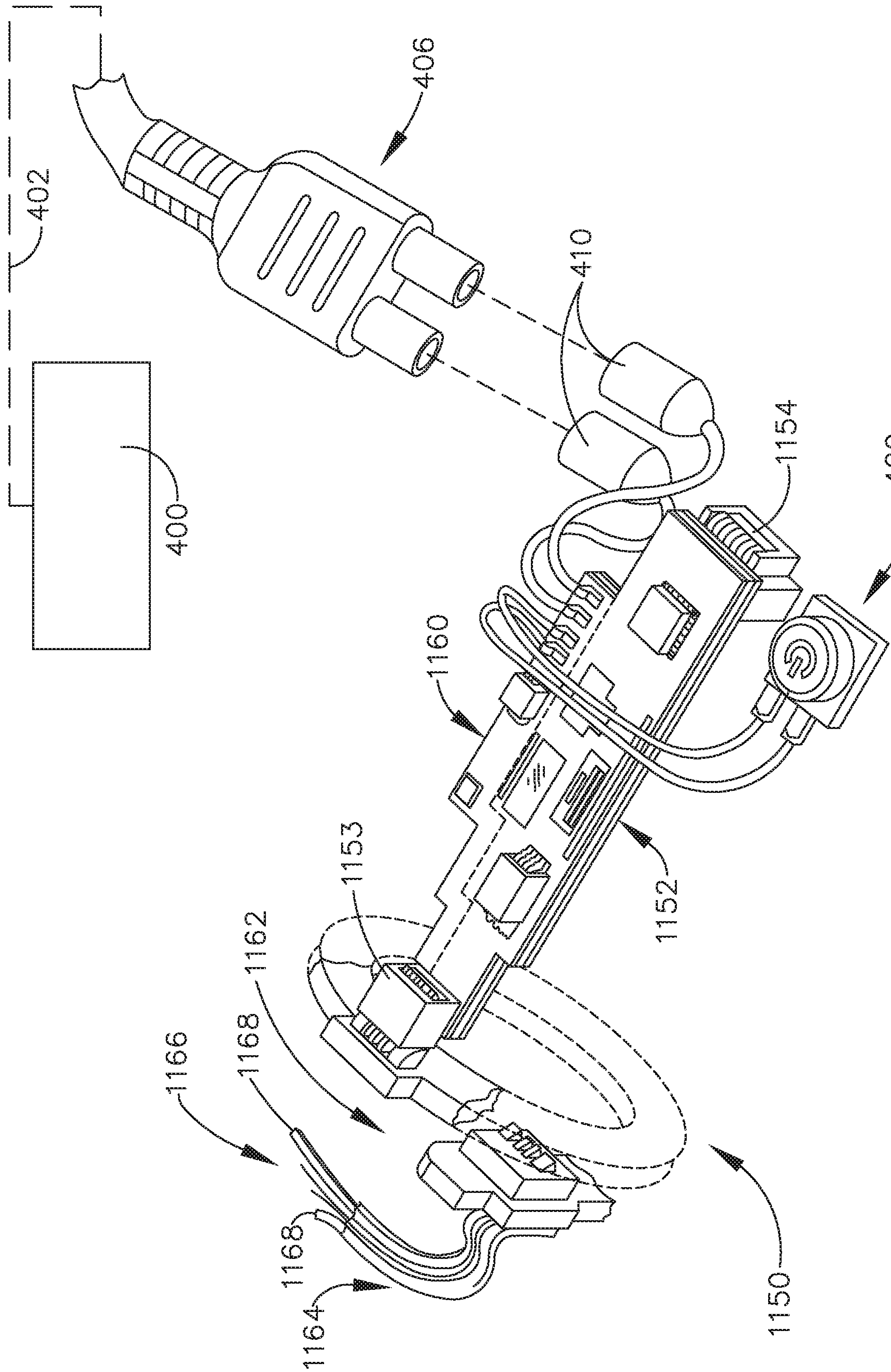

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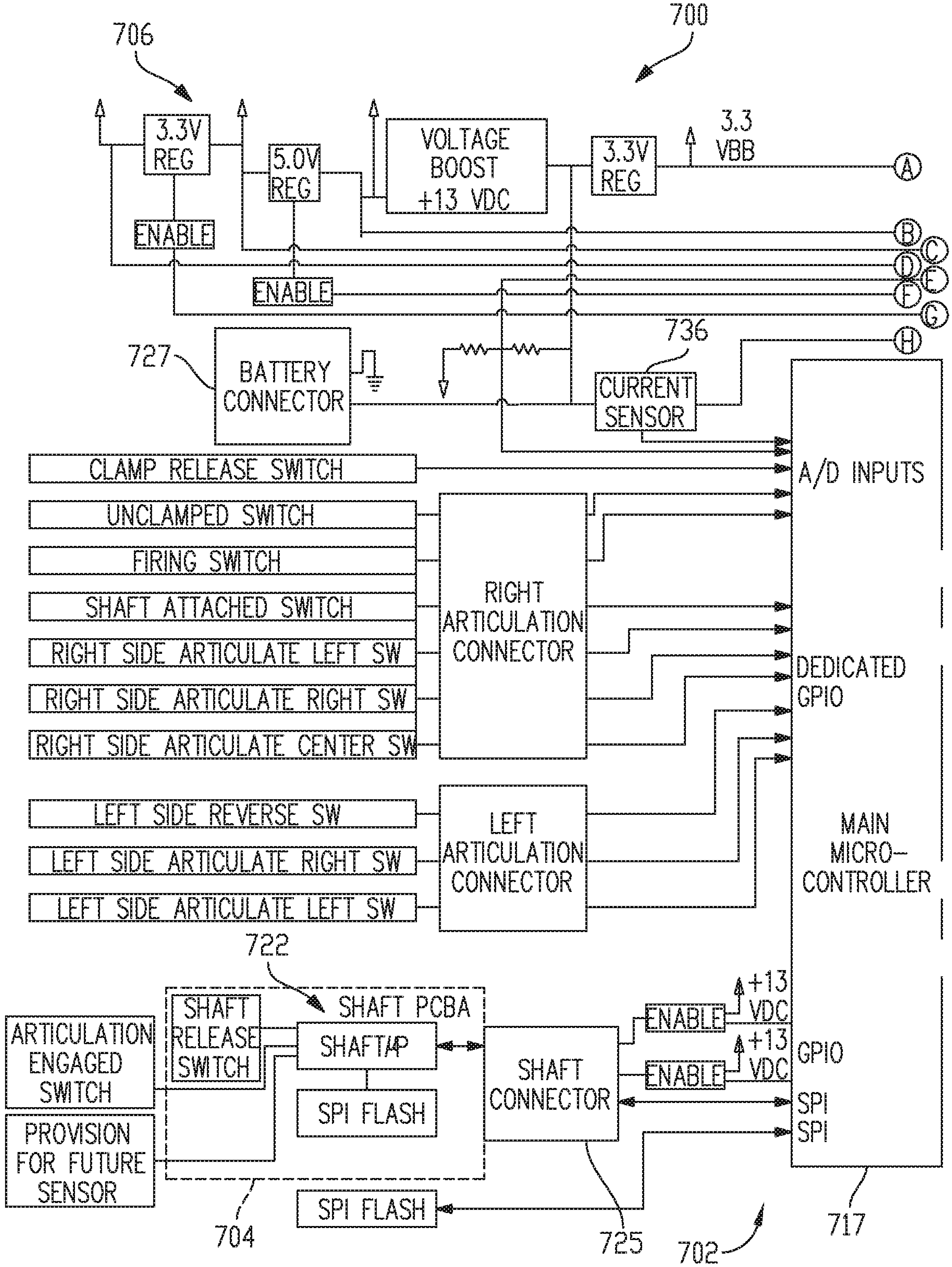
FIG. 15



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706
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5.0V REG
VOLTAGE BOOST +13 VDC
3.3V REG
3.3 VBB
A
B
C
D
E
F
G
H
ENABLE
ENABLE
727
BATTERY CONNECTOR
736
CURRENT SENSOR
CLAMP RELEASE SWITCH
UNCLAMPED SWITCH
FIRING SWITCH
SHAFT ATTACHED SWITCH
RIGHT SIDE ARTICULATE LEFT SW
RIGHT SIDE ARTICULATE RIGHT SW
RIGHT SIDE ARTICULATE CENTER SW
RIGHT ARTICULATION CONNECTOR
LEFT SIDE REVERSE SW
LEFT SIDE ARTICULATE RIGHT SW
LEFT SIDE ARTICULATE LEFT SW
LEFT ARTICULATION CONNECTOR
A/D INPUTS
DEDICATED GPIO
MAIN MICRO-CONTROLLER
722
SHAFT PCBA
ARTICULATION ENGAGED SWITCH
SHAFT RELEASE SWITCH
SHAFT μP
SPI FLASH
PROVISION FOR FUTURE SENSOR
SHAFT CONNECTOR
ENABLE
+13 VDC
ENABLE
+13 VDC
GPIO
SPI
SPI
SPI FLASH
704
725
702
717

FIG. 16A

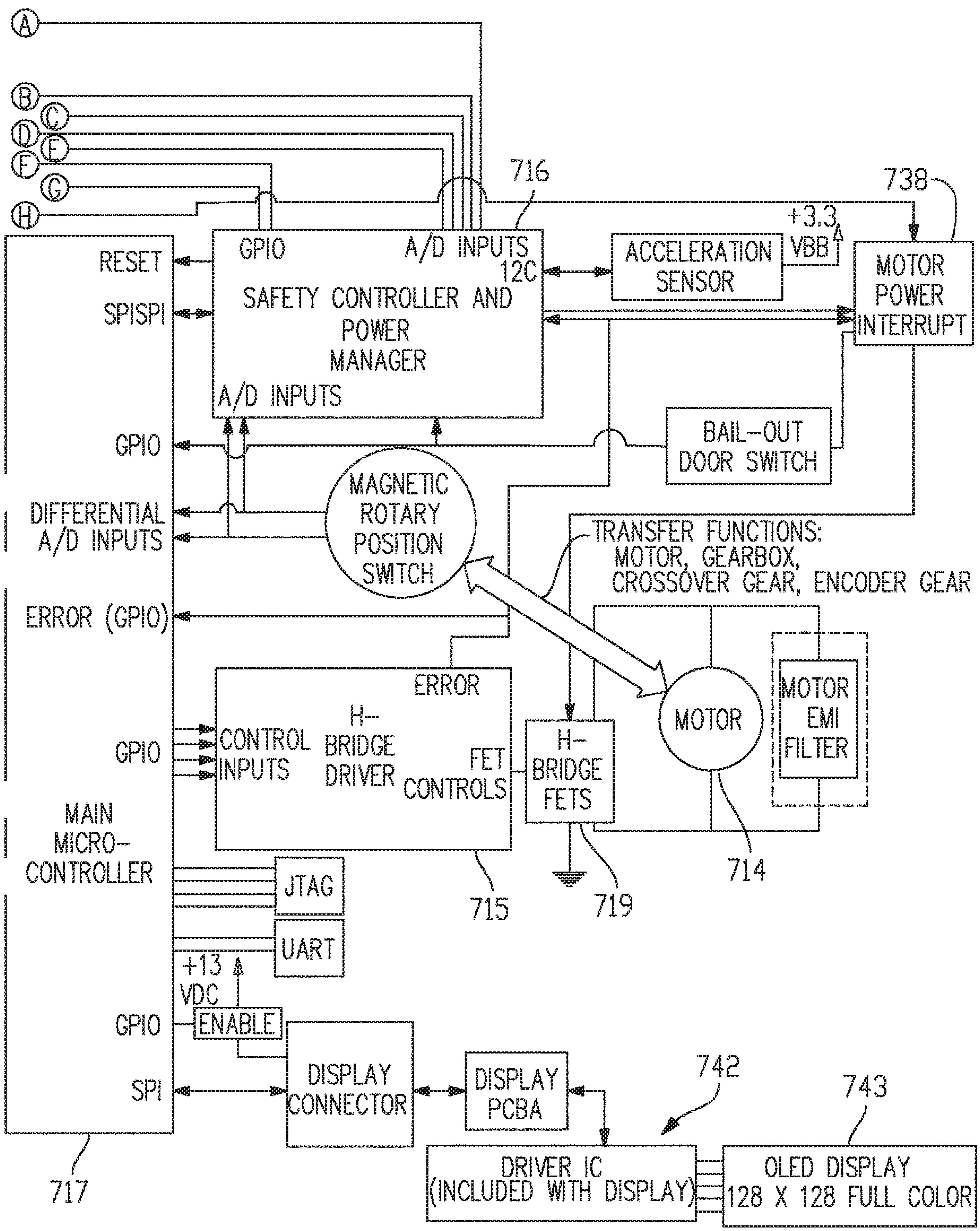

A
B
C
D
E
F
G
H
716
738
GPIO
A/D INPUTS
12C
SAFETY CONTROLLER AND POWER MANAGER
A/D INPUTS
ACCELERATION SENSOR
+3.3 VBB
MOTOR POWER INTERRUPT
RESET
SPISPI
GPIO
BAIL-OUT DOOR SWITCH
MAGNETIC ROTARY POSITION SWITCH
DIFFERENTIAL A/D INPUTS
TRANSFER FUNCTIONS: MOTOR, GEARBOX, CROSSOVER GEAR, ENCODER GEAR
ERROR (GPIO)
ERROR
H-BRIDGE DRIVER
CONTROL INPUTS
FET CONTROLS
H-BRIDGE FETS
MOTOR
MOTOR EMI FILTER
GPIO
MAIN MICRO-CONTROLLER
JTAG
UART
715
719
714
+13 VDC
ENABLE
GPIO
SPI
DISPLAY CONNECTOR
DISPLAY PCBA
742
743
DRIVER IC (INCLUDED WITH DISPLAY)
OLED DISPLAY 128 X 128 FULL COLOR
717

FIG. 16B

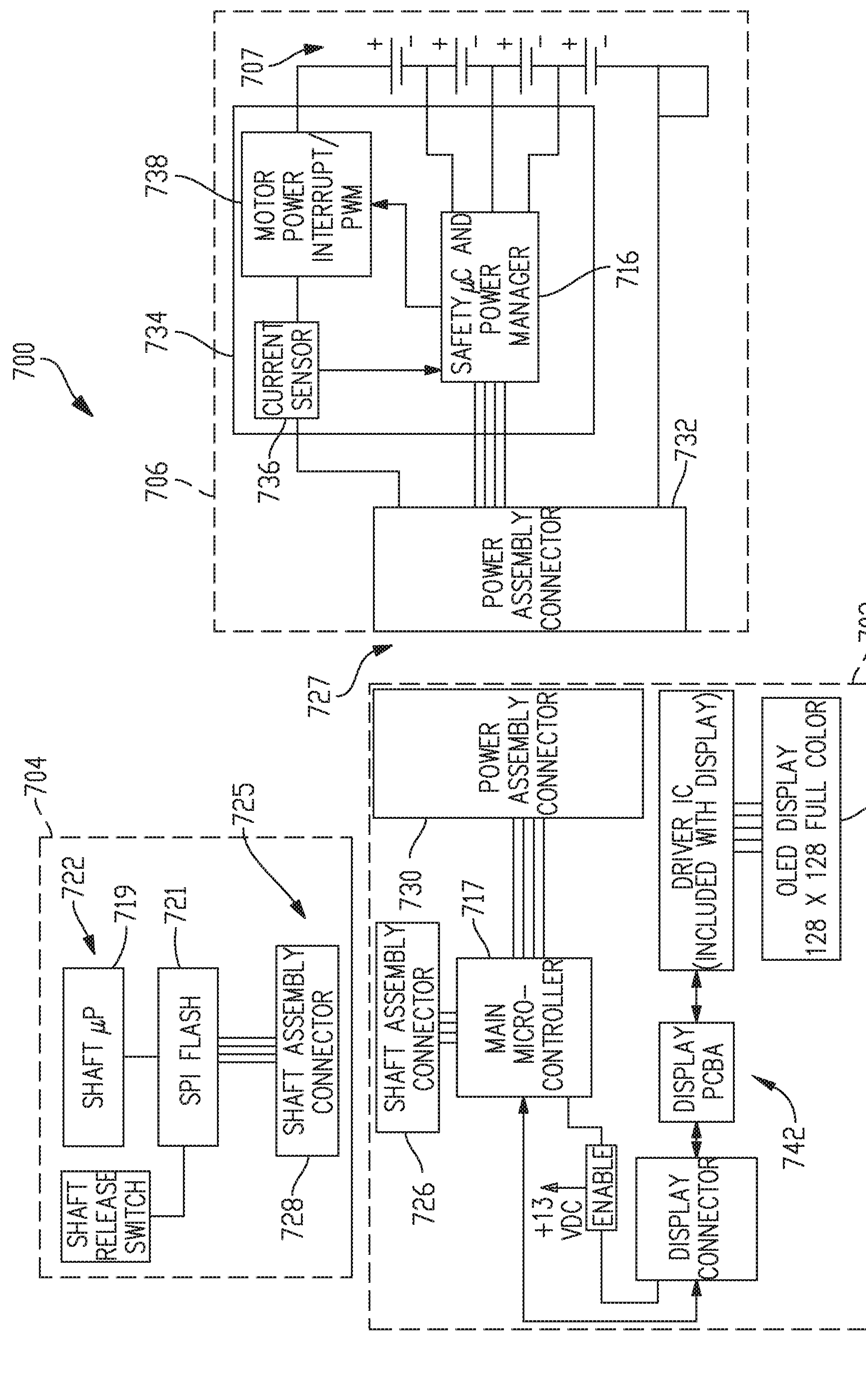

700
707
738
MOTOR POWER INTERRUPT/ PWM
734
CURRENT SENSOR
SAFETY μC AND POWER MANAGER
716
706
736
732
POWER ASSEMBLY CONNECTOR
727
702
704
722
719
SHAFT μP
721
SPI FLASH
725
SHAFT ASSEMBLY CONNECTOR
728
SHAFT RELEASE SWITCH
POWER ASSEMBLY CONNECTOR
730
717
SHAFT ASSEMBLY CONNECTOR
726
MAIN MICRO-CONTROLLER
DRIVER IC (INCLUDED WITH DISPLAY)
OLED DISPLAY 128 X 128 FULL COLOR
743
DISPLAY PCBA
742
ENABLE
+13 VDC
DISPLAY CONNECTOR

FIG. 17

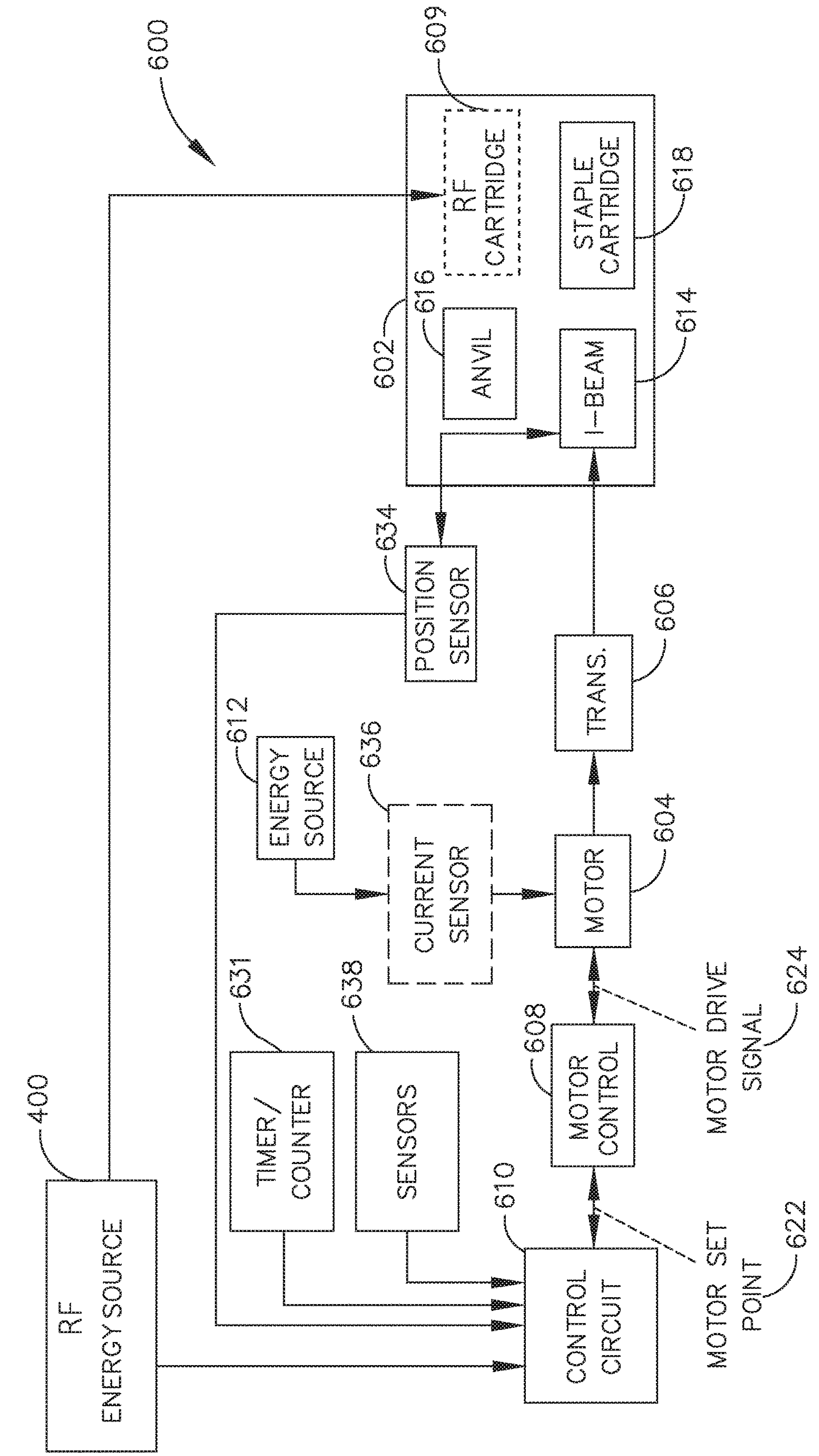
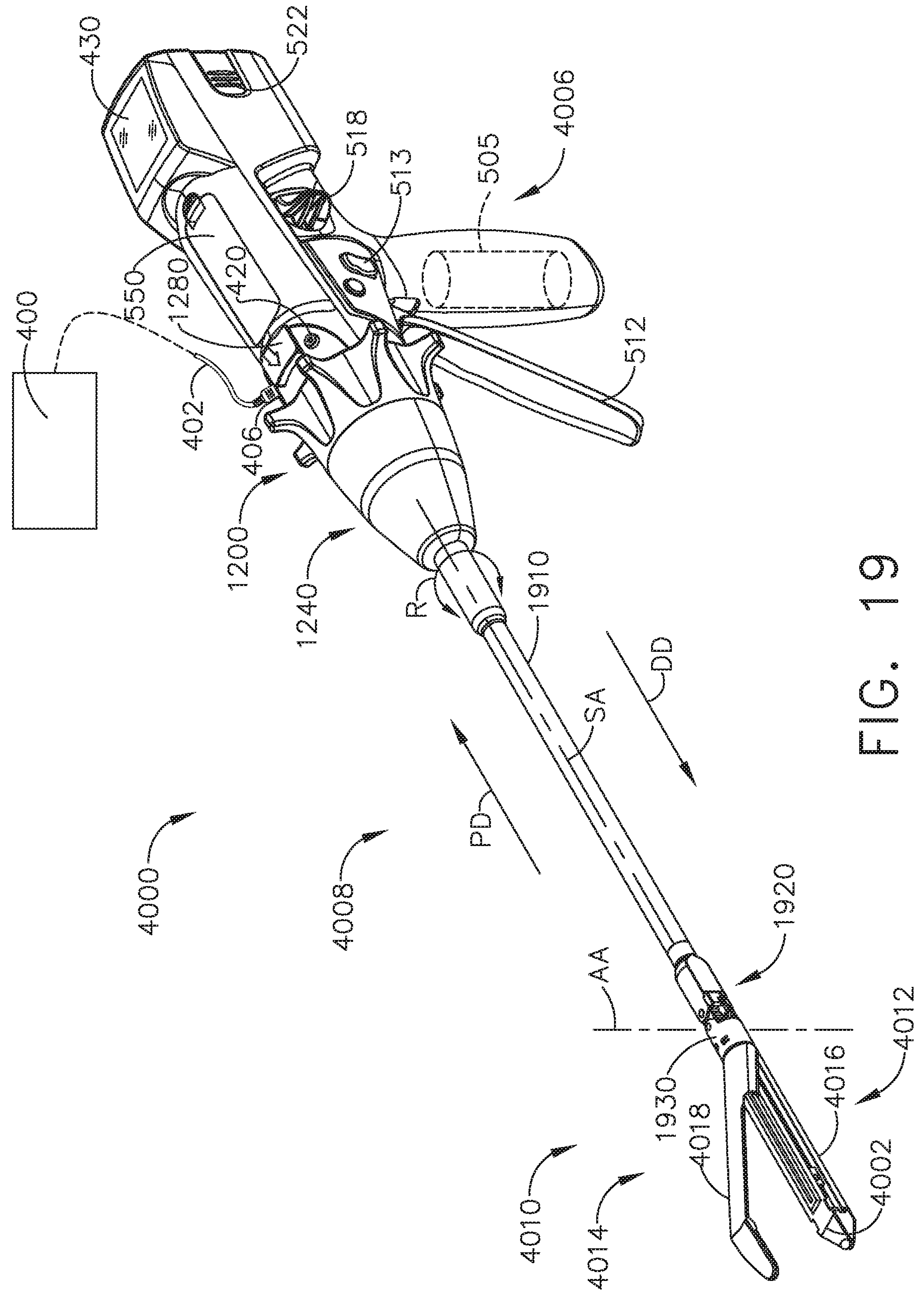

600
609
RF CARTRIDGE
STAPLE CARTRIDGE
618
602
616
ANVIL
I—BEAM
614
634
POSITION SENSOR
606
TRANS.
612
ENERGY SOURCE
636
CURRENT SENSOR
MOTOR
604
631
TIMER/ COUNTER
638
SENSORS
608
MOTOR CONTROL
MOTOR DRIVE SIGNAL
624
400
RF ENERGY SOURCE
610
CONTROL CIRCUIT
MOTOR SET POINT
622

FIG. 18



430
522
4006
518
513
505
400
550
1280
420
512
402
406
1200
1240
R
1910
DD
SA
PD
4000
4008
1920
AA
4012
4016
1930
4018
4002
4010
4014

FIG. 19

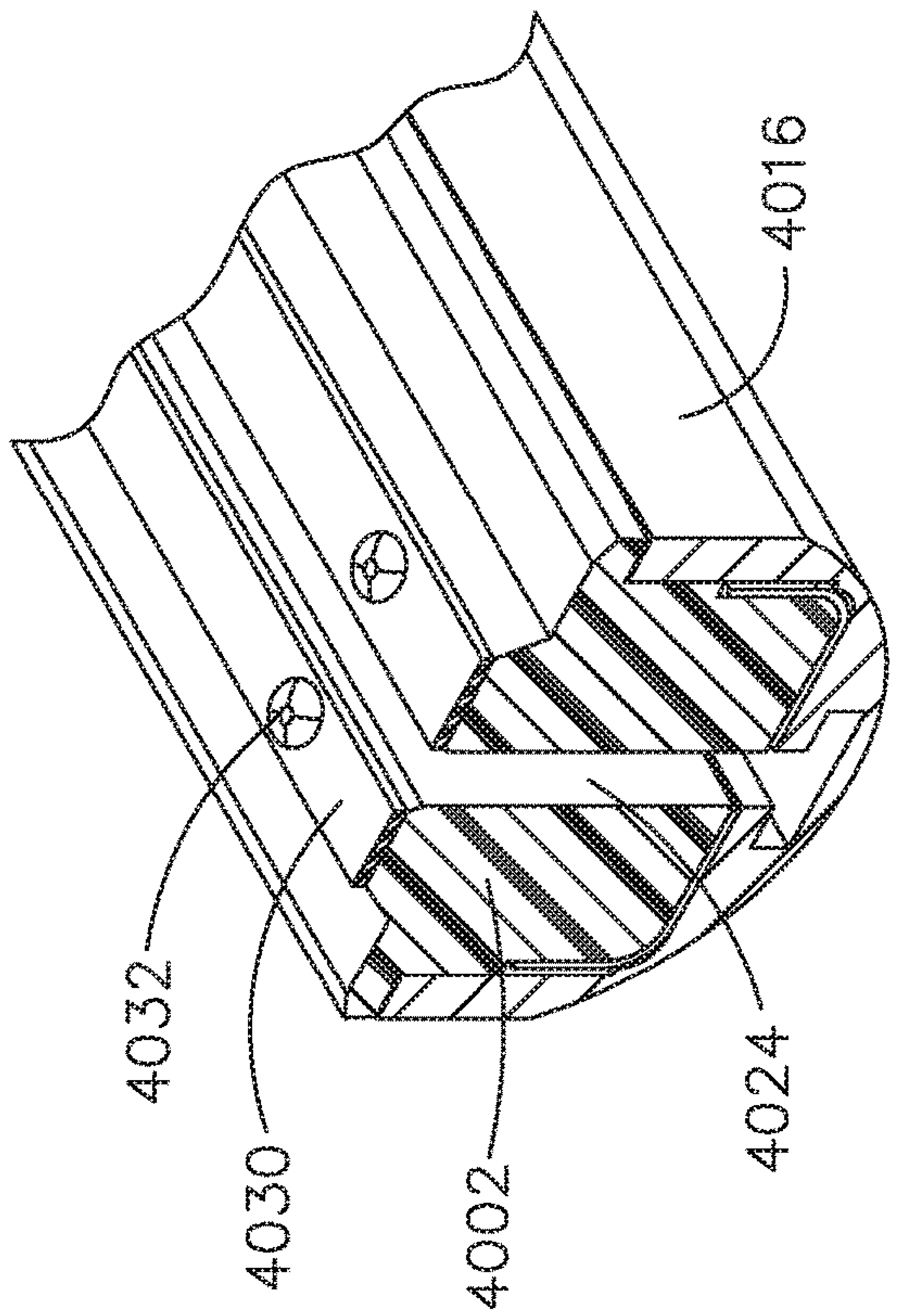

4016
4032
4030
4002
4024

FIG. 20

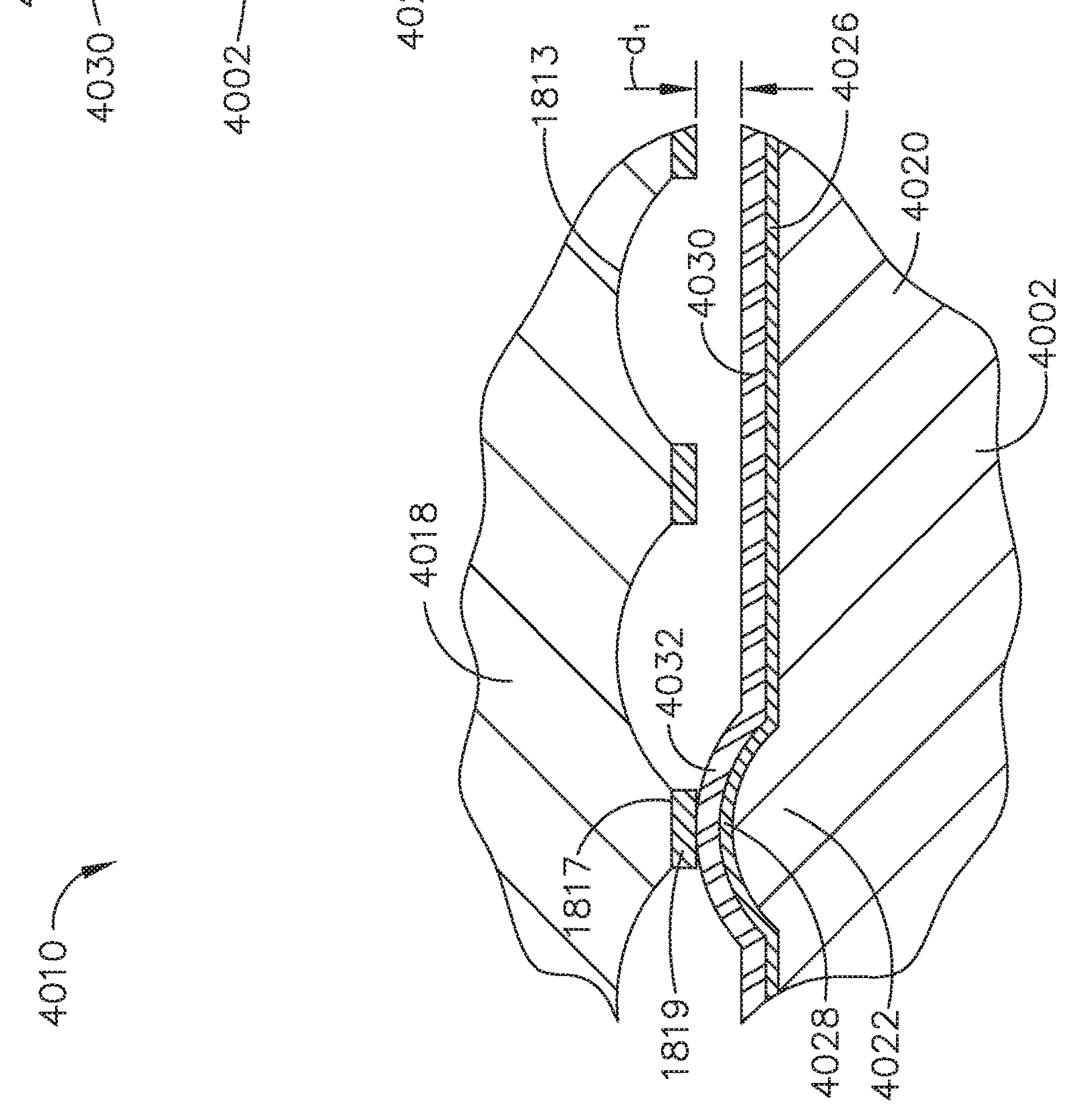

4010
1813
d_1
4026
4020
4030
4002
4018
4032
1817
1819
4028
4022

FIG. 21

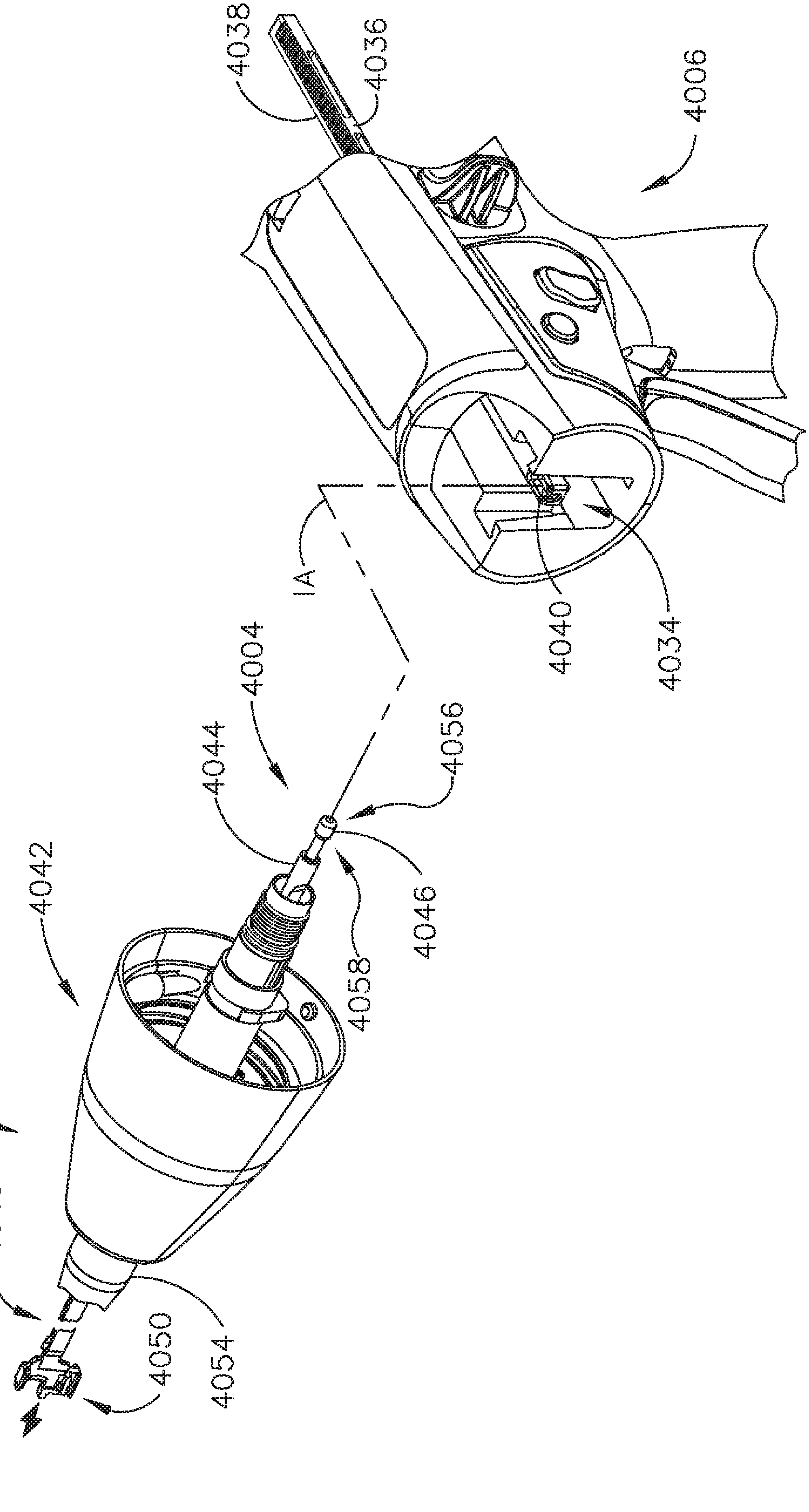

4038
4036
4006
4040
4034
IA
4004
4044
4056
4042
4046
4058
4008
4043
4050
4054

FIG. 22

SURGICAL SYSTEM COUPLEABLE WITH STAPLE CARTRIDGE AND RADIO FREQUENCY CARTRIDGE, AND HAVING A PLURALITY OF RADIO-FREQUENCY ENERGY RETURN PATHS

TECHNICAL FIELD

The present disclosure relates to electrosurgical devices and, in various aspects, to compressive jaw components that are designed to conduct electrical energy into a tissue compressed therewith.

BACKGROUND

In some aspects, an electrosurgical device may be configured to induce a hemostatic seal in a tissue and/or between tissues. The hemostatic seal may be created by a combination of an applied compressive force to the tissue and an application of electrical energy to the tissue. In some aspects of an electrosurgical device, the compressive force may be supplied by a compression of the tissue between jaw assemblies. Additionally, the electrical energy may be supplied by one or more electrodes disposed within or on some components of the jaw assemblies. The amount of electrical energy sufficient to effect the hemostatic seal may depend, in part, on the thickness, density, and/or quality of tissue to be sealed.

It may be understood that an application of excessive electrical energy to a tissue may result in burning or scaring of the tissue. However, the application of insufficient electrical energy to a tissue may result in an ineffective hemostatic seal. Thus, a user of the electrosurgical device may be required to adjust the amount of electrical energy delivered to the tissue compressed between the jaw assemblies of the device based on the tissue thickness, density, and quality. If a tissue compressed between the jaw assemblies is essentially homogeneous, the user of the electrosurgical device may use simple controls to adjust the amount of electrical energy delivered to the tissue. However, it may be recognized that some tissues for hemostatic sealing are inhomogeneous in any one or more of their thickness, density, and/or quality. As a result, a single control for the amount of electrical energy delivered to the tissue compressed between the jaw assemblies may result in burned portions as well as insufficiently sealed portions of the tissue. It is therefore desirable to have an electrosurgical device that may be configured to deliver a variety of electrical energies to a piece of tissue compressed between the jaw assemblies.

SUMMARY

In one aspect, an interchangeable tool assembly is provided. The interchangeable tool assembly comprises a first jaw configured to support a staple cartridge during a first time period and a radio-frequency cartridge during a second time period; a second jaw coupled to the first jaw, wherein a surface of the second jaw defines a plurality of staple forming pockets configured to form staples driven from the staple cartridge; and an electrically insulative material covering segments of the surface of the second jaw other than the staple forming pockets, wherein the staple forming pockets define at least one return path for radio-frequency energy delivered by the radio-frequency cartridge.

In another aspect, a surgical tool assembly is provided. The surgical tool assembly, comprises an elongate channel configured to support a staple cartridge during a first time period and a radio-frequency cartridge during a second time period; and an anvil coupled to the elongate channel, wherein the anvil comprises: a surface which faces the elongate channel and defines a plurality of staple forming pockets configured to form staples driven from the staple cartridge; and an electrically insulative material which covers segments of the surface of the second jaw, wherein the plurality of staple forming pockets provide for a plurality of different return paths for radio-frequency energy delivered by the radio-frequency cartridge.

In another aspect, an interchangeable tool assembly is provided. The interchangeable tool assembly comprises an end effector configured to releasably couple to a shaft assembly, wherein the end effector comprises: an elongate channel configured to support a staple cartridge during a first time period and a radio-frequency cartridge during a second time period; and an anvil coupled to the elongate channel, wherein the anvil comprises an electrically insulative material and defines a plurality of different return paths for radio-frequency energy delivered by the radio-frequency cartridge.

FIGURES

The novel features of the aspects described herein are set forth with particularity in the appended claims. These aspects, however, both as to organization and methods of operation may be better understood by reference to the following description, taken in conjunction with the accompanying drawings.

FIG. **1** is a perspective view of a surgical system including a handle assembly coupled to an interchangeable surgical tool assembly that is configured to be used in connection with conventional surgical staple/fastener cartridges and radio frequency (RF) cartridges according to one aspect of this disclosure.

FIG. **2** is an exploded perspective assembly view of the surgical system of FIG. **1** according to one aspect of this disclosure.

FIG. **3** is another exploded perspective assembly view of portions of the handle assembly and interchangeable surgical tool assembly of FIGS. **1** and **2** according to one aspect of this disclosure.

FIG. **4** is an exploded assembly view of a proximal portion of the interchangeable surgical tool assembly of FIGS. **1-3** according to one aspect of this disclosure.

FIG. **5** is another exploded assembly view of a distal portion of the interchangeable surgical tool assembly of FIGS. **1-5** according to one aspect of this disclosure.

FIG. **6** is a partial cross-sectional view of the end effector depicted in FIGS. **1-5** supporting an RF cartridge therein and with tissue clamped between the cartridge and the anvil according to one aspect of this disclosure.

FIG. **7** is a partial cross-sectional view of the anvil of FIG. **6** according to one aspect of this disclosure.

FIG. **8** is another exploded assembly view of a portion of the interchangeable surgical tool assembly of FIGS. **1-5** according to one aspect of this disclosure.

FIG. **9** is another exploded assembly view of the interchangeable surgical tool assembly and handle assembly of FIGS. **1** and **2** according to one aspect of this disclosure.

FIG. **10** is a perspective view of an RF cartridge and an elongate channel of the interchangeable surgical tool assembly of FIGS. **1-5** according to one aspect of this disclosure.

FIG. **11** is a partial perspective view of portions of the RF cartridge and elongate channel of FIG. **10** with a knife member according to one aspect of this disclosure.

FIG. **12** is another perspective view of the RF cartridge installed in the elongate channel of FIG. **10** and illustrating a portion of a flexible shaft circuit arrangement according to one aspect of this disclosure.

FIG. **13** is a cross-sectional end view of the RF cartridge and elongate channel of FIG. **12** taken along lines **13-13** in FIG. **12** according to one aspect of this disclosure.

FIG. **14** is a top cross-sectional view of a portion of the interchangeable surgical tool assembly of FIGS. **1** and **5** with the end effector thereof in an articulated position according to one aspect of this disclosure.

FIG. **15** is a perspective view of an onboard circuit board arrangement and RF generator plus configuration according to one aspect of this disclosure.

FIGS. **16**A-**16**B is a block diagram of a control circuit of the surgical instrument of FIG. **1** spanning two drawing sheets according to one aspect of this disclosure.

FIG. **17** is a block diagram of the control circuit of the surgical instrument of FIG. **1** illustrating interfaces between the handle assembly, the power assembly, and the handle assembly and the interchangeable shaft assembly according to one aspect of this disclosure.

FIG. **18** is a schematic diagram of a surgical instrument configured to control various functions according to one aspect of this disclosure.

FIG. **19** is a perspective view of various aspects of a surgical system according to one aspect of this disclosure.

FIG. **20** is a partial cross-section of an end effector of the surgical system of FIG. **19** according to one aspect of this disclosure.

FIG. **21** is a partial perspective view of a radio-frequency cartridge supported by an elongate channel of the end effector of FIG. **20** according to one aspect of this disclosure.

FIG. **22** is an exploded perspective assembly view of portions of a handle assembly and an interchangeable tool assembly of the surgical system of FIG. **19** according to one aspect of this disclosure.

DESCRIPTION

Applicant of the present application owns the following patent applications filed Jun. 28, 2017, and which are each herein incorporated by reference in their respective entireties:

U.S. patent application Ser. No. 15/636,096, titled SURGICAL SYSTEM COUPLABLE WITH STAPLE CARTRIDGE AND RADIO FREQUENCY CARTRIDGE, AND METHOD OF USING SAME, by inventors Jeffrey D. Messerly et al., filed Jun. 28, 2017, now U.S. Patent Application Publication No. 2019/0000478.

U.S. patent application Ser. No. 15/636,103, titled SYSTEMS AND METHODS OF DISPLAYING SURGICAL INSTRUMENT STATUS, by inventors Jeffrey D. Messerly et al., filed Jun. 28, 2017, now U.S. Patent Application Publication No. 2019/0000533.

U.S. patent application Ser. No. 15/636,110, titled SHAFT MODULE CIRCUITRY ARRANGEMENTS, by inventors Jeffrey D. Messerly et al., filed Jun. 28, 2017, now U.S. Patent Application Publication No. 2019/0000525.

U.S. patent application Ser. No. 15/636,116, titled SYSTEMS AND METHODS FOR CONTROLLING CONTROL CIRCUITS FOR INDEPENDENT ENERGY DELIVERY OVER SEGMENTED SECTIONS, by inventors Jeffrey D. Messerly et al., filed Jun. 28, 2017, now U.S. Patent Application Publication No. 2019/0000534.

U.S. patent application Ser. No. 15/636,123, titled FLEXIBLE CIRCUIT ARRANGEMENT FOR SURGICAL FASTENING INSTRUMENTS, by inventors Jeffrey D. Messerly et al., filed Jun. 28, 2017, now U.S. Patent Application Publication No. 2019/0000531.

U.S. patent application Ser. No. 15/636,144, titled SYSTEMS AND METHODS FOR CONTROLLING CONTROL CIRCUITS FOR AN INDEPENDENT ENERGY DELIVERY OVER SEGMENTED SECTIONS, by inventors David C. Yates et al., filed Jun. 28, 2017, now U.S. Pat. No. 10,265,120.

U.S. patent application Ser. No. 15/636,150, titled SURGICAL END EFFECTOR FOR APPLYING ELECTROSURGICAL ENERGY TO DIFFERENT ELECTRODES ON DIFFERENT TIME PERIODS, by inventors Tamara Widenhouse et al., filed Jun. 28, 2017, now U.S. Patent Application Publication No. 2019/0000537.

U.S. patent application Ser. No. 15/636,162, titled ELECTROSURGICAL CARTRIDGE FOR USE IN THIN PROFILE SURGICAL CUTTING AND STAPLING INSTRUMENT, by inventors Tamara Wdenhouse et al., now U.S. Patent Application Publication No. 2019-0000538.

U.S. patent application Ser. No. 15/636,169, titled SURGICAL END EFFECTOR TO ADJUST JAW COMPRESSION, by inventors Frederick E. Shelton, I V et al., filed Jun. 28, 2017, now U.S. Patent Application Publication No. 2019/0000532.

U.S. patent application Ser. No. 15/636,177, titled CARTRIDGE ARRANGEMENTS FOR SURGICAL CUTTING AND FASTENING INSTRUMENTS WITH LOCKOUT DISABLEMENT FEATURES, by inventors Jason L. Harris et al., filed Jun. 28, 2017, now U.S. Patent Application Publication No. 2019/0000479.

U.S. patent application Ser. No. 15/636,180, titled SURGICAL CUTTING AND FASTENING INSTRUMENTS WITH DUAL POWER SOURCES, by inventors Jeffrey D. Messerly et al., filed Jun. 28, 2017, now U.S. Patent Application Publication No. 2019/0000539.

Electrosurgical devices may be used in many surgical operations. Electrosurgical devices may apply electrical energy to tissue in order to treat tissue. An electrosurgical device may comprise an instrument having a distally mounted end effector comprising one or more electrodes. The end effector can be positioned against tissue such that electrical current may be introduced into the tissue. Electrosurgical devices can be configured for monopolar or bipolar operation. During monopolar operation, current may be introduced into the tissue by an active (or source) electrode on the end effector and returned through a return electrode. The return electrode may be a grounding pad and separately located on a patient's body. During bipolar operation, current may be introduced into and returned from the tissue by the active and return electrodes, respectively, of the end effector.

The end effector may include two or more jaw members. At least one of the jaw members may have at least one electrode. At least one jaw may be movable from a position spaced apart from the opposing jaw for receiving tissues to a position in which the space between the jaw members is less than that of the first position. This movement of the movable jaw may compress the tissue held between. Heat generated by the current flow through the tissue in combination with the compression achieved by the jaw's movement may form hemostatic seals within the tissue and/or between tissues and, thus, may be particularly useful for sealing blood vessels, for example. The end effector may comprise a cutting member. The cutting member may be movable relative to the tissue and the electrodes to transect the tissue.

Electrosurgical devices also may include mechanisms to clamp tissue together, such as a stapling device, and/or mechanisms to sever tissue, such as a tissue knife. An electrosurgical device may include a shaft for placing the end effector proximate to tissue undergoing treatment. The shaft may be straight or curved, bendable or non-bendable. In an electrosurgical device including a straight and bendable shaft, the shaft may have one or more articulation joints to permit controlled bending of the shaft. Such joints may permit a user of the electrosurgical device to place the end effector in contact with tissue at an angle to the shaft when the tissue being treated is not readily accessible using an electrosurgical device having a straight, non-bending shaft.

Electrical energy applied by electrosurgical devices can be transmitted to the instrument by a generator in communication with the hand piece. The electrical energy may be in the form of radio frequency ("RF") energy. RF energy is a form of electrical energy that may be in the frequency range of 200 kilohertz (kHz) to 1 megahertz (MHz). In application, an electrosurgical instrument can transmit low frequency RF energy through tissue, which causes ionic agitation, or friction, in effect resistive heating, thereby increasing the temperature of the tissue. Because a sharp boundary is created between the affected tissue and the surrounding tissue, surgeons can operate with a high level of precision and control, without sacrificing un-targeted adjacent tissue. The low operating temperatures of RF energy is useful for removing, shrinking, or sculpting soft tissue while simultaneously sealing blood vessels. RF energy works particularly well on connective tissue, which is primarily comprised of collagen and shrinks when contacted by heat.

The RF energy may be in a frequency range described in EN 60601-2-2:2009+A11:2011, Definition 201.3.218—HIGH FREQUENCY. For example, the frequency in monopolar RF applications may be typically restricted to less than 5 MHz. However, in bipolar RF applications, the frequency can be almost anything. Frequencies above 200 kHz can be typically used for monopolar applications in order to avoid the unwanted stimulation of nerves and muscles that would result from the use of low frequency current. Lower frequencies may be used for bipolar applications if the risk analysis shows the possibility of neuromuscular stimulation has been mitigated to an acceptable level. Normally, frequencies above 5 MHz are not used in order to minimize the problems associated with high frequency leakage currents. Higher frequencies may, however, be used in the case of bipolar applications. It is generally recognized that 10 mA is the lower threshold of thermal effects on tissue.

FIGS. **1** and **2** depict a motor-driven surgical system **10** that may be used to perform a variety of different surgical procedures. In the illustrated arrangement, the surgical system **10** comprises an interchangeable surgical tool assembly **1000** that is operably coupled to a handle assembly **500**. In another surgical system aspect, the interchangeable surgical tool assembly **1000** may also be effectively employed with a tool drive assembly of a robotically controlled or automated surgical system. For example, the surgical tool assembly **1000** disclosed herein may be employed with various robotic systems, instruments, components and methods such as, but not limited to, those disclosed in U.S. Pat. No. 9,072,535, entitled SURGICAL STAPLING INSTRUMENTS WITH ROTATABLE STAPLE DEPLOYMENT ARRANGEMENTS, which is hereby incorporated by reference herein in its entirety.

In the illustrated aspect, the handle assembly **500** may comprise a handle housing **502** that includes a pistol grip portion that can be gripped and manipulated by the clinician. As will be briefly discussed below, the handle assembly **500** operably supports a plurality of drive systems that are configured to generate and apply various control motions to corresponding portions of the interchangeable surgical tool assembly **1000**. As shown in FIG. **2**, the handle assembly **500** may further include a handle frame **506** that operably supports the plurality of drive systems. For example, the handle frame **506** can operably support a "first" or closure drive system, generally designated as **510**, which may be employed to apply closing and opening motions to the interchangeable surgical tool assembly **1000**. In at least one form, the closure drive system **510** may include an actuator in the form of a closure trigger **512** that is pivotally supported by the handle frame **506**. Such arrangement enables the closure trigger **512** to be manipulated by a clinician such that when the clinician grips the pistol grip portion of the handle assembly **500**, the closure trigger **512** may be easily pivoted from a starting or "unactuated" position to an "actuated" position and more particularly to a fully compressed or fully actuated position. In use, to actuate the closure drive system **510**, the clinician depresses the closure trigger **512** towards the pistol grip portion. As described in further detail in U.S. patent application Ser. No. 14/226,142, entitled SURGICAL INSTRUMENT COMPRISING A SENSOR SYSTEM, now U.S. Patent Application Publication No. 2015/0272575, which is hereby incorporated by reference in its entirety herein, when the clinician fully depresses the closure trigger **512** to attain the full closure stroke, the closure drive system **510** is configured to lock the closure trigger **512** into the fully depressed or fully actuated position. When the clinician desires to unlock the closure trigger **512** to permit it to be biased to the unactuated position, the clinician simply activates a closure release button assembly **518** which enables the closure trigger to return to unactuated position. The closure release button assembly **518** may also be configured to interact with various sensors that communicate with a microcontroller in the handle assembly **500** for tracking the position of the closure trigger **512**. Further details concerning the configuration and operation of the closure release button assembly **518** may be found in U.S. Patent Application Publication No. 2015/0272575.

In at least one form, the handle assembly **500** and the handle frame **506** may operably support another drive system referred to herein as a firing drive system **530** that is configured to apply firing motions to corresponding portions of the interchangeable surgical tool assembly that is attached thereto. As was described in detail in U.S. Patent Application Publication No. 2015/0272575, the firing drive system **530** may employ an electric motor **505** that is located in the pistol grip portion of the handle assembly **500**. In various forms, the motor **505** may be a DC brushed driving motor having a maximum rotation of, approximately, 25,000 RPM, for example. In other arrangements, the motor **505** may include a brushless motor, a cordless motor, a synchronous motor, a stepper motor, or any other suitable electric motor. The motor **505** may be powered by a power source **522** that in one form may comprise a removable power pack. The power pack may support a plurality of Lithium Ion ("LI") or other suitable batteries therein. A number of batteries connected in series or parallel may be used as the power source **522** for the surgical system **10**. In addition, the power source **522** may be replaceable and/or rechargeable.

The electric motor **505** is configured to axially drive a longitudinally movable drive member **540** (FIG. **3**) in a distal and proximal directions depending upon the polarity of the motor. For example, when the motor **505** is driven in one rotary direction, the longitudinally movable drive member will be axially driven in a distal direction "DD". When the motor **505** is driven in the opposite rotary direction, the longitudinally movable drive member **540** will be axially driven in a proximal direction "PD". The handle assembly **500** can include a switch **513** which can be configured to reverse the polarity applied to the electric motor **505** by the power source **522** or otherwise control the motor **505**. The handle assembly **500** can also include a sensor or sensors (not shown) that is configured to detect the position of the drive member and/or the direction in which the drive member is being moved. Actuation of the motor **505** can be controlled by a firing trigger (not shown) that is adjacent to the closure trigger **512** and pivotally supported on the handle assembly **500**. The firing trigger may be pivoted between an unactuated position and an actuated position. The firing trigger may be biased into the unactuated position by a spring or other biasing arrangement such that when the clinician releases the firing trigger, it may be pivoted or otherwise returned to the unactuated position by the spring or biasing arrangement. In at least one form, the firing trigger can be positioned "outboard" of the closure trigger **512**. As discussed in U.S. Patent Application Publication No. 2015/0272575, the handle assembly **500** may be equipped with a firing trigger safety button (not shown) to prevent inadvertent actuation of the firing trigger. When the closure trigger **512** is in the unactuated position, the safety button is contained in the handle assembly **500** where the clinician cannot readily access it and move it between a safety position preventing actuation of the firing trigger and a firing position wherein the firing trigger may be fired. As the clinician depresses the closure trigger, the safety button and the firing trigger pivot down wherein they can then be manipulated by the clinician.

In at least one form, the longitudinally movable drive member **540** may have a rack of teeth **542** formed thereon for meshing engagement with a corresponding drive gear arrangement (not shown) that interfaces with the motor. See FIG. **3**. Further details regarding those features may be found in U.S. Patent Application Publication No. 2015/0272575. In at least one arrangement, however, the longitudinally movable drive member is insulated to protect it from inadvertent RF energy. At least one form also includes a manually-actuatable "bailout" assembly that is configured to enable the clinician to manually retract the longitudinally movable drive member should the motor **505** become disabled. The bailout assembly may include a lever or bailout handle assembly that is stored within the handle assembly **500** under a releasable door **550**. See FIG. **2**. The lever may be configured to be manually pivoted into ratcheting engagement with the teeth in the drive member. Thus, the clinician can manually retract the drive member **540** by using the bailout handle assembly to ratchet the drive member in the proximal direction "PD". U.S. Pat. No. 8,608,045, entitled POWERED SURGICAL CUTTING AND STAPLING APPARATUS WITH MANUALLY RETRACTABLE FIRING SYSTEM, the entire disclosure of which is hereby incorporated by reference herein, discloses bailout arrangements and other components, arrangements and systems that may also be employed with any one of the various interchangeable surgical tool assemblies disclosed herein.

In the illustrated aspect, the interchangeable surgical tool assembly **1000** includes a surgical end effector **1500** that comprises a first jaw **1600** and a second jaw **1800**. In one arrangement, the first jaw comprises an elongate channel **1602** that is configured to operably support a conventional (mechanical) surgical staple/fastener cartridge **1400** (FIG. **4**) or a radio frequency (RF) cartridge **1700** (FIGS. **1** and **2**) therein. The second jaw **1800** comprises an anvil **1810** that is pivotally supported relative to the elongate channel **1602**. The anvil **1810** may be selectively moved toward and away from a surgical cartridge supported in the elongate channel **1602** between open and closed positions by actuating the closure drive system **510**. In the illustrated arrangement, the anvil **1810** is pivotally supported on a proximal end portion of the elongate channel **1602** for selective pivotal travel about a pivot axis that is transverse to the shaft axis SA. Actuation of the closure drive system **510** may result in the distal axial movement of a proximal closure member or proximal closure tube **1910** that is attached to an articulation connector **1920**.

Turning to FIG. **4**, the articulation connector **1920** includes upper and lower tangs **1922**, **1924** protrude distally from a distal end of the articulation connector **1920** to be movably coupled to an end effector closure sleeve or distal closure tube segment **1930**. See FIG. **3**. The distal closure tube segment **1930** includes an upper tang **1932** and a lower tang (not shown) that protrude proximally from a proximal end thereof. An upper double pivot link **1940** includes proximal and distal pins **1941**, **1942** that engage corresponding holes in the upper tangs **1922**, **1932** of the articulation connector **1920** and distal closure tube segment **1930**, respectively. Similarly, a lower double pivot link **1944** includes proximal and distal pins **1945**, **1946** that engage corresponding holes in the lower tangs **1924** of the articulation connector **1920** and distal closure tube segment **1930**, respectively.

Still referring to FIG. **4**, in the illustrated example, the distal closure tube segment **1930** includes positive jaw opening features or tabs **1936**, **1938** that correspond with corresponding portions of the anvil **1810** to apply opening motions to the anvil **1810** as the distal closure tube segment **1930** is retracted in the proximal direction PD to a starting position. Further details regarding the opening and closing of the anvil **1810** may be found in U.S. patent application Ser. No. 15/635,621, entitled SURGICAL INSTRUMENT WITH POSITIVE JAW OPENING FEATURES, filed on Jun. 28, 2017, the entire disclosure of which is hereby incorporated by reference herein.

As shown in FIG. **5**, in at least one arrangement, the interchangeable surgical tool assembly **1000** includes a tool frame assembly **1200** that comprises a tool chassis **1210** that operably supports a nozzle assembly **1240** thereon. As further discussed in detail in U.S. Patent Application Ser. No. 15/635,631, entitled SURGICAL INSTRUMENT WITH AXIALLY MOVABLE CLOSURE MEMBER, filed on Jun. 28, 2017, now U.S. Pat. No. 10,639,037, and which is hereby incorporated by reference in its entirety herein, the tool chassis **1210** and nozzle arrangement **1240** facilitate rotation of the surgical end effector **1500** about a shaft axis SA relative to the tool chassis **1210**. Such rotational travel is represented by arrow R in FIG. **1**. As also shown in FIGS. **4** and **5**, the interchangeable surgical tool assembly **1000** includes a spine assembly **1250** that operably supports the proximal closure tube **1910** and is coupled to the surgical end effector **1500**. In various circumstances, for ease of assembly, the spine assembly **1250** may be fabricated from an upper spine segment **1251** and a lower spine segment **1252** that are interconnected together by snap features, adhesive, welding, etc. In assembled form, the spine assembly **1250** includes a proximal end **1253** that is rotatably supported in the tool chassis **1210**. In one arrangement, for example, the proximal end **1253** of the spine assembly **1250** is attached to a spine bearing (not shown) that is configured to be supported within the tool chassis **1210**. Such arrangement facilitates rotatable attachment of the spine assembly **1250** to the tool chassis such that the spine assembly **1250** may be selectively rotated about a shaft axis SA relative to the tool chassis **1210**.

As shown in FIG. **4**, the upper spine segment **1251** terminates in an upper lug mount feature **1260** and the lower spine segment **1252** terminates in a lower lug mount feature **1270**. The upper lug mount feature **1260** is formed with a lug slot **1262** therein that is adapted to mountingly support an upper mounting link **1264** therein. Similarly, the lower lug mount feature **1270** is formed with a lug slot **1272** therein that is adapted to mountingly support a lower mounting link **1274** therein. The upper mounting link **1264** includes a pivot socket **1266** therein that is offset from the shaft axis SA. The pivot socket **1266** is adapted to rotatably receive therein a pivot pin **1634** that is formed on a channel cap or anvil retainer **1630** that is attached to a proximal end portion **1610** of the elongate channel **1602**. The lower mounting link **1274** includes lower pivot pin **1276** that adapted to be received within a pivot hole **1611** formed in the proximal end portion **1610** of the elongate channel **1602**. The lower pivot pin **1276** as well as the pivot hole **1611** is offset from the shaft axis SA. The lower pivot pin **1276** is vertically aligned with the pivot socket **1266** to define the articulation axis AA about which the surgical end effector **1500** may articulate relative to the shaft axis SA. See FIG. **1**. Although the articulation axis AA is transverse to the shaft axis SA, in at least one arrangement, the articulation axis AA is laterally offset therefrom and does not intersect the shaft axis SA.

Turning to FIG. **5**, a proximal end **1912** of the proximal closure tube **1910** is rotatably coupled to a closure shuttle **1914** by a connector **1916** that is seated in an annular groove **1915** in the proximal closure tube segment **1910**. The closure shuttle **1914** is supported for axial travel within the tool chassis **1210** and has a pair of hooks **1917** thereon configured to engage the closure drive system **510** when the tool chassis **1210** is coupled to the handle frame **506** (FIG. **9**). The tool chassis **1210** further supports a latch assembly **1280** for releasably latching the tool chassis **1210** to the handle frame **506**. Further details regarding the tool chassis **1210** and latch assembly **1280** may be found in U.S. patent application Ser. No. 15/635,631, entitled SURGICAL INSTRUMENT WITH AXIALLY MOVABLE CLOSURE MEMBER, filed on Jun. 28, 2017, the entire disclosure of which is hereby incorporated by reference herein.

The firing drive system **530** in the handle assembly **500** is configured to be operably coupled to a firing system **1300** that is operably supported in the interchangeable surgical tool assembly **1000**. The firing system **1300** may include an intermediate firing shaft portion **1310** that is configured to be axially moved in the distal and proximal directions in response to corresponding firing motions applied thereto by the firing drive system **530**. See FIG. **4**. As shown in FIG. **5**, a proximal end **1312** of the intermediate firing shaft portion **1310** has a firing shaft attachment lug **1314** formed thereon that is configured to be seated into an attachment cradle **544** (FIG. **3**) that is on the distal end of the longitudinally movable drive member **540** of the firing drive system **530** within the handle assembly **500**. Such arrangement facilitates the axial movement of the intermediate firing shaft portion **1310** upon actuation of the firing drive system **530**. In the illustrated example, the intermediate firing shaft portion **1310** is configured for attachment to a distal cutting portion or knife bar **1320**. As shown in FIG. **4**, the knife bar **1320** is connected to a firing member or knife member **1330**.

The knife member **1330** comprises a knife body **1332** that operably supports a tissue cutting blade **1334** thereon. The knife body **1332** may further include anvil engagement tabs or features **1336** and channel engagement features or a foot **1338**. The anvil engagement features **1336** may serve to apply additional closure motions to the anvil **1810** as the knife member **1330** is advanced distally through the end effector **1500**.

In the illustrated example, the surgical end effector **1500** is selectively articulatable about the articulation axis AA by an articulation system **1360**. In one form, the articulation system **1360** includes proximal articulation driver **1370** that is pivotally coupled to an articulation link **1380**. As can be most particularly seen in FIG. **4**, an offset attachment lug **1373** is formed on a distal end **1372** of the proximal articulation driver **1370**. A pivot hole **1374** is formed in the offset attachment lug **1373** and is configured to pivotally receive therein a proximal link pin **1382** formed on the proximal end **1381** of the articulation link **1380**. A distal end **1383** of the articulation link **1380** includes a pivot hole **1384** that is configured to pivotally receive therein a channel pin **1618** formed on the proximal end portion **1610** of the elongate channel **1602**. Thus, axial movement of proximal articulation driver **1370** will thereby apply articulation motions to the elongate channel **1602** to thereby cause the surgical end effector **1500** to articulate about the articulation axis AA relative to the spine assembly **1250**. In various circumstances, the proximal articulation driver **1370** can be held in position by an articulation lock **1390** when the proximal articulation driver **1370** is not being moved in the proximal or distal directions. Further details regarding an example form of articulation lock **1390** may be found in U.S. patent application Ser. No. 15/635,837 entitled SURGICAL INSTRUMENT COMPRISING AN ARTICULATION SYSTEM LOCKABLE TO A FRAME, filed on Jun. 28, 2017, the entire disclosure of which is hereby incorporated by reference herein.

Further to the above, the interchangeable surgical tool assembly **1000** can include a shifter assembly **1100** which can be configured to selectively and releasably couple the proximal articulation driver **1310** to the firing system **1300**. As illustrated in FIG. **5**, for example, in one form, the shifter assembly **1100** includes a lock collar, or lock sleeve **1110**, positioned around the intermediate firing shaft portion **1310** of the firing system **1300** wherein the lock sleeve **1110** can be rotated between an engaged position in which the lock sleeve **1110** operably couples the proximal articulation driver **1370** to the firing member assembly **1300** and a disengaged position in which the proximal articulation driver **1370** is not operably coupled to the firing member assembly **1300**. When lock sleeve **1110** is in its engaged position, distal movement of the firing member assembly **1300** can move the proximal articulation driver **1370** distally and, correspondingly, proximal movement of the firing member assembly **1300** can move the proximal articulation driver **1370** proximally. When lock sleeve **1110** is in its disengaged position, movement of the firing member assembly **1300** is not transmitted to the proximal articulation driver **1370** and, as a result, the firing member assembly **1300** can move independently of the proximal articulation driver **1370**. In various circumstances, the proximal articulation driver **1370** can be held in position by the articulation lock **1390** when the proximal articulation driver **1370** is not being moved in the proximal or distal directions by the firing member assembly **1300**.

In the illustrated arrangement, the intermediate firing shaft portion **1310** of the firing member assembly **1300** is formed with two opposed flat sides with a drive notch **1316** formed therein. See FIG. **5**. As can also be seen in FIG. **5**, the lock sleeve **1110** comprises a cylindrical, or an at least substantially cylindrical, body that includes a longitudinal aperture that is configured to receive the intermediate firing shaft portion **1310** therethrough. The lock sleeve **1110** can comprise diametrically-opposed, inwardly-facing lock protrusions that, when the lock sleeve **1110** is in one position, are engagingly received within corresponding portions of the drive notch **1316** in the intermediate firing shaft portion **1310** and, when in another position, are not received within the drive notch **1316** to thereby permit relative axial motion between the lock sleeve **1110** and the intermediate firing shaft **1310**. As can be further seen in FIG. **5**, the lock sleeve **1110** further includes a lock member **1112** that is sized to be movably received within a notch **1375** in a proximal end of the proximal articulation driver **1370**. Such arrangement permits the lock sleeve **1110** to slightly rotate into and out of engagement with the intermediate firing shaft portion **1310** while remaining in position for engagement or in engagement with the notch **1375** in the proximal articulation driver **1370**. For example, when the lock sleeve **1110** is in its engaged position, the lock protrusions are positioned within the drive notch **1316** in the intermediate firing shaft portion **1310** such that a distal pushing force and/or a proximal pulling force can be transmitted from the firing member assembly **1300** to the lock sleeve **1110**. Such axial pushing or pulling motion is then transmitted from the lock sleeve **1110** to the proximal articulation driver **1370** to thereby articulate the surgical end effector **1500**. In effect, the firing member assembly **1300**, the lock sleeve **1110**, and the proximal articulation driver **1370** will move together when the lock sleeve **1110** is in its engaged (articulation) position. On the other hand, when the lock sleeve **1110** is in its disengaged position, the lock protrusions are not received within the drive notch **1316** in the intermediate firing shaft portion **1310** and, as a result, a distal pushing force and/or a proximal pulling force may not be transmitted from the firing member assembly **1300** to the lock sleeve **1110** (and the proximal articulation driver **1370**).

In the illustrated example, relative movement of the lock sleeve **1110** between its engaged and disengaged positions may be controlled by the shifter assembly **1100** that interfaces with the proximal closure tube **1910**. Still referring to FIG. **5**, the shifter assembly **1100** further includes a shifter key **1120** that is configured to be slidably received within a key groove formed in the outer perimeter of the lock sleeve **1110**. Such arrangement enables the shifter key **1120** to move axially with respect to the lock sleeve **1110**. As discussed in further detail in U.S. patent application Ser. No. 15/635,631, entitled SURGICAL INSTRUMENT WITH AXIALLY MOVABLE CLOSURE MEMBER, filed on Jun. 28, 2017, the entire disclosure of which is hereby incorporated by reference herein, a portion of the shifter key **1120** is configured to cammingly interact with a cam opening (not shown) in the proximal closure tube portion **1910**. Also in the illustrated example, the shifter assembly **1100** further includes a switch drum **1130** that is rotatably received on a proximal end portion of the proximal closure tube portion **1910**. A portion of the shifter key **1120** extends through an axial slot segment in the switch drum **1130** and is movably received within an arcuate slot segment in the switch drum **1130**. A switch drum torsion spring **1132** is mounted on the switch drum **1130** and engages a portion of the nozzle assembly **1240** to apply a torsional bias or rotation which serves to rotate the switch drum **1130** until the portion of the shifter key **1120** reaches an end portion of the cam opening in the proximal closure tube portion **1910**. When in this position, the switch drum **1130** may provide a torsional bias to the shifter key **1120** which thereby causes the lock sleeve **1110** to rotate into its engaged position with the intermediate firing shaft portion **1310**. This position also corresponds to the unactuated configuration of the proximal closure tube **1910** (and distal closure tube segment **1930**).

In one arrangement, for example, when the proximal closure tube **1910** is in an unactuated configuration (anvil **1810** is in an open position spaced away from the cartridge mounted in the elongate channel **1602**) actuation of the intermediate firing shaft portion **1310** will result in the axial movement of the proximal articulation driver **1370** to facilitate articulation of the end effector **1500**. Once the user has articulated the surgical end effector **1500** to a desired orientation, the user may then actuate the proximal closure tube portion **1910**. Actuation of the proximal closure tube portion **1910** will result in the distal travel of the distal closure tube segment **1930** to ultimately apply a closing motion to the anvil **1810**. This distal travel of the proximal closure tube portion **1910** will result in the cam opening therein cammingly interacting with a cam portion of the shifter key **1120** to thereby cause the shifter key **1120** to rotate the lock sleeve **1110** in an actuation direction. Such rotation of the lock sleeve **1110** will result in the disengagement of the lock protrusions from the drive notch **1316** in the intermediate firing shaft portion **1310**. When in such configuration, the firing drive system **530** may be actuated to actuate the intermediate firing shaft portion **1310** without actuating the proximal articulation driver **1370**. Further details concerning the operation of the switch drum **1130** and lock sleeve **1110**, as well as alternative articulation and firing drive arrangements that may be employed with the various interchangeable surgical tool assemblies described herein, may be found in U.S. patent application Ser. No. 13/803,086, now U.S. Patent Application Publication No. 2014/0263541, and U.S. patent application Ser. No. 15/019,196, the entire disclosures of which are hereby incorporated by reference herein.

As also illustrated in FIGS. **5** and **15**, the interchangeable surgical tool assembly **1000** can comprise a slip ring assembly **1150** which can be configured to conduct electrical power to and/or from the surgical end effector **1500** and/or communicate signals to and/or from the surgical end effector **1500**, back to an onboard circuit board **1152**, while facilitating rotational travel of the shaft and end effector **1500** about the shaft axis SA relative to the tool chassis **1210** by rotating the nozzle assembly **1240**. As shown in FIG. **15**, in at least one arrangement, the onboard circuit board **1152** includes an onboard connector **1154** that is configured to interface with a housing connector **562** (FIG. **9**) communicating with a microprocessor **560** (FIG. **9**) that is supported in the handle assembly **500** (FIG. **9**) or robotic system controller, for example. The slip ring assembly **1150** is configured to interface with a proximal connector **1153** that interfaces with the onboard circuit board **1152**. Further details concerning the slip ring assembly **1150** and associated connectors may be found in U.S. patent application Ser. No. 13/803,086, now U.S. Patent Application Publication No. 2014/0263541, and U.S. patent application Ser. No. 15/019,196 which have each been herein incorporated by reference in their respective entirety as well as in U.S. patent application Ser. No. 13/800,067, entitled STAPLE CARTRIDGE TISSUE THICKNESS SENSOR SYSTEM, now U.S. Patent Application Publication No. 2014/0263552, which is hereby incorporated by reference herein in its entirety.

An example version of the interchangeable surgical tool assembly **1000** disclosed herein may be employed in connection with a standard (mechanical) surgical fastener cartridge **1400** or a cartridge **1700** that is configured to facilitate cutting of tissue with the knife member and seal the cut tissue using radio frequency (RF) energy. Turning again to FIG. **4**, a conventional or standard mechanical-type cartridge **1400** is depicted. Such cartridge arrangements are known and may comprise a cartridge body **1402** that is sized and shaped to be removably received and supported in the elongate channel **1602**. For example, the cartridge body **1402** may be configured to be removably retained in snap engagement with the elongate channel **1602**. The cartridge body **1402** includes an elongate slot **1404** to accommodate axial travel of the knife member **1330** therethrough. The cartridge body **1402** operably supports therein a plurality of staple drivers (not shown) that are aligned in rows on each side of the centrally disposed elongate slot **1404**. The drivers are associated with corresponding staple/fastener pockets **1412** that open through the upper deck surface **1410** of the cartridge body **1402**. Each of the staple drivers supports one or more surgical staple or fastener (not shown) thereon. A sled assembly **1420** is supported within a proximal end of the cartridge body **1402** and is located proximal to the drivers and fasteners in a starting position when the cartridge **1400** is new and unfired. The sled assembly **1420** includes a plurality of sloped or wedge-shaped cams **1422** wherein each cam **1422** corresponds to a particular line of fasteners or drivers located on a side of the slot **1404**. The sled assembly **1420** is configured to be contacted and driven by the knife member **1330** as the knife member is driven distally through the tissue that is clamped between the anvil and the cartridge deck surface **1410**. As the drivers are driven upward toward the cartridge deck surface **1410**, the fastener(s) supported thereon are driven out of their staple pockets **1412** and through the tissue that is clamped between anvil and the cartridge.

Still referring to FIG. **4**, the anvil **1810** in at least one form includes an anvil mounting portion **1820** that has a pair of anvil trunnions **1822** protruding laterally therefrom to be pivotally received in corresponding trunnion cradles formed in the upstanding walls **1622** of the proximal end portion **1610** of the elongate channel **1602**. The anvil trunnions **1822** are pivotally retained in their corresponding trunnion cradle by the channel cap or anvil retainer **1630**. The anvil mounting portion **1820** is movably or pivotably supported on the elongate channel **1602** for selective pivotal travel relative thereto about a fixed anvil pivot axis that is transverse to the shaft axis SA. As shown in FIGS. **6** and **7**, in at least one form, the anvil **1810** includes an anvil body portion **1812** that is fabricated from an electrically conductive metal material for example and has a staple forming undersurface **1813** that has a series of fastener forming pockets **1814** formed therein on each side of a centrally disposed anvil slot **1815** that is configured to slidably accommodate the knife member **1330** therein. The anvil slot **1815** opens into an upper opening **1816** that extends longitudinally through the anvil body **1812** to accommodate the anvil engagement features **1336** on the knife member **1330** during firing. When a conventional mechanical surgical staple/fastener cartridge **1400** is installed in the elongate channel **1602**, the staples/fasteners are driven through the tissue T and into forming contact with the corresponding fastener forming pockets **1814**. The anvil body **1812** may have an opening in the upper portion thereof to facilitate ease of installation for example. An anvil cap **1818** may be inserted therein and welded to the anvil body **1812** to enclose the opening and improve the overall stiffness of the anvil body **1812**. As shown in FIG. **7**, to facilitate use of the end effector **1500** in connection with RF cartridges **1700**, the tissue facing segments **1817** of the fastener forming undersurface **1813** may have electrically insulative material **1819** thereon.

In the illustrated arrangement, the interchangeable surgical tool assembly **1000** is configured with a firing member lockout system, generally designated as **1640**. See FIG. **8**. As shown in FIG. **8**, the elongate channel **1602** includes a bottom surface or bottom portion **1620** that has two upstanding side walls **1622** protruding therefrom. A centrally disposed longitudinal channel slot **1624** is formed through the bottom portion **1620** to facilitate the axial travel of the knife member **1330** therethrough. The channel slot **1624** opens into a longitudinal passage **1626** that accommodates the channel engagement feature or foot **1338** on the knife member **1330**. The passage **1626** serves to define two inwardly extending ledge portions **1628** that serve to engage corresponding portions of the channel engagement feature or foot **1338**. The firing member lockout system **1640** includes proximal openings **1642** located on each side of the channel slot **1624** that are each configured to receive corresponding portions of the channel engagement feature or foot **1338** when the knife member **1330** is in a starting position. A knife lockout spring **1650** is supported in the proximal end **1610** of the elongate channel **1602** and serves to bias the knife member **1330** downward. As shown in FIG. **8**, the knife lockout spring **1650** includes two distally ending spring arms **1652** that are configured to engage corresponding central channel engagement features **1337** on the knife body **1332**. The spring arms **1652** are configured to bias the central channel engagement features **1337** downward. Thus, when in the starting (unfired position), the knife member **1330** is biased downward such that the channel engagement features or foot **1338** is received within the corresponding proximal openings **1642** in the elongate **1602** channel. When in that locked position, if one were to attempt to distally advance the knife **1330**, the central channel engagement features **1137** and/or foot **1338** would engage upstanding ledges **1654** on the elongate channel **1602** (FIGS. **8** and **11**) and the knife **1330** could not be fired.

Still referring to FIG. **8**, the firing member lockout system **1640** also includes an unlocking assembly **1660** formed or supported on a distal end of the firing member body **1332**. The unlocking assembly **1660** includes a distally extending ledge **1662** that is configured to engage an unlocking feature **1426** formed on the sled assembly **1420** when the sled assembly **1420** is in its starting position in an unfired surgical staple cartridge **1400**. Thus, when an unfired surgical staple cartridge **1400** is properly installed in the elongate channel **1602**, the ledge **1662** on the unlocking assembly **1660** contacts the unlocking feature **1426** on the sled assembly **1420** which serves to bias the knife member **1330** upward such that the central channel engagement features **1137** and/or foot **1338** clear the upstanding ledges **1654** in the channel bottom **1620** to facilitate axial passage of the knife member **1330** through the elongate channel **1602**. If a partially fired cartridge **1400** is unwittingly installed in the elongate channel, the sled assembly **1420** will not be in the starting position and the knife member **1330** will remain in the locked position.

Attachment of the interchangeable surgical tool assembly **1000** to the handle assembly **500** will now be described with reference to FIGS. **3** and **9**. To commence the coupling process, the clinician may position the tool chassis **1210** of the interchangeable surgical tool assembly **1000** above or adjacent to the distal end of the handle frame **506** such that tapered attachment portions **1212** formed on the tool chassis **1210** are aligned with dovetail slots **507** in the handle frame **506**. The clinician may then move the surgical tool assembly **1000** along an installation axis IA that is perpendicular to the shaft axis SA to seat the tapered attachment portions **1212** in "operable engagement" with the corresponding dovetail receiving slots **507** in the distal end of the handle frame **506**. In doing so, the firing shaft attachment lug **1314** on the intermediate firing shaft portion **1310** will also be seated in the cradle **544** in the longitudinally movable drive member **540** within the handle assembly **500** and the portions of a pin **516** on a closure link **514** will be seated in the corresponding hooks **1917** in the closure shuttle **1914**. As used herein, the term "operable engagement" in the context of two components means that the two components are sufficiently engaged with each other so that upon application of an actuation motion thereto, the components may carry out their intended action, function and/or procedure. Also during this process, the onboard connector **1154** on the surgical tool assembly **1000** is coupled to the housing connector **562** that communicates with the microprocessor **560** that is supported in the handle assembly **500** or robotic system controller, for example.

During a typical surgical procedure, the clinician may introduce the surgical end effector **1500** into the surgical site through a trocar or other opening in the patient to access the target tissue. When doing so, the clinician typically axially aligns the surgical end effector **1500** along the shaft axis SA (unarticulated state). Once the surgical end effector **1500** has passed through the trocar port, for example, the clinician may need to articulate the end effector **1500** to advantageously position it adjacent the target tissue. This is prior to closing the anvil **1810** onto the target tissue, so the closure drive system **510** would remain unactuated. When in this position, actuation of the firing drive system **530** will result in the application of articulation motions to the proximal articulation driver **1370**. Once the end effector **1500** has attained the desired articulated position, the firing drive system **530** is deactivated and the articulation lock **1390** may retain the surgical end effector **1500** in the articulated position. The clinician may then actuate the closure drive system **510** to close the anvil **1810** onto the target tissue. Such actuation of the closure drive system **510** may also result in the shifter assembly **1100** delinking the proximal articulation driver **1370** from the intermediate firing shaft portion **1310**. Thus, once the target tissue has been captured in the surgical end effector **1500**, the clinician may once again actuate the firing drive system **530** to axially advance the firing member **1330** through the surgical staple/fastener cartridge **1400** or RF cartridge **1700** to cut the clamped tissue and fire the staples/fasteners into the cut tissue T. Other closure and firing drive arrangements, actuator arrangements (both handheld, manual and automated or robotic) may also be employed to control the axial movement of the closure system components, the articulation system components and/or the firing system components of the surgical tool assembly **1000** without departing from the scope of the present disclosure.

As indicated above, the surgical tool assembly **1000** is configured to be used in connection with conventional mechanical surgical staple/fastener cartridges **1400** as well as with RF cartridges **1700**. In at least one form, the RF cartridge **1700** may facilitate mechanical cutting of tissue that is clamped between the anvil **1810** and the RF cartridge **1700** with the knife member **1330** while coagulating electrical current is delivered to the tissue in the current path. Alternative arrangements for mechanically cutting and coagulating tissue using electrical current are disclosed in, for example, U.S. Pat. Nos. 5,403,312; 7,780,663 and U.S. patent application Ser. No. 15/142,609, entitled ELECTROSURGICAL INSTRUMENT WITH ELECTRICALLY CONDUCTIVE GAP SETTING AND TISSUE ENGAGING MEMBERS, the entire disclosures of each said references being incorporated by reference herein. Such instruments, may, for example, improve hemostasis, reduce surgical complexity as well as operating room time.

As shown in FIGS. **10-12**, in at least one arrangement, the RF surgical cartridge **1700** includes a cartridge body **1710** that is sized and shaped to be removably received and supported in the elongate channel **1602**. For example, the cartridge body **1710** may be configured to be removably retained in snap engagement with the elongate channel **1602**. In various arrangements, the cartridge body **1710** may be fabricated from a polymer material, such as, for example, an engineering thermoplastic such as the liquid crystal polymer (LCP) VECTRA™ and the elongate channel **1602** may be fabricated from metal. In at least one aspect, the cartridge body **1710** includes a centrally disposed elongate slot **1712** that extends longitudinally through the cartridge body to accommodate longitudinal travel of the knife **1330** therethrough. As shown in FIGS. **10** and **11**, a pair of lockout engagement tails **1714** extend proximally from the cartridge body **1710**. Each lockout engagement tail **1714** has a lockout pad **1716** formed on the underside thereof that are sized to be received within a corresponding proximal opening portion **1642** in the channel bottom **1620**. Thus, when the cartridge **1700** is properly installed in the elongate channel **1602**, the lockout engagement tails **1714** cover the openings **1642** and ledges **1654** to retain the knife **1330** in an unlocked position ready for firing.

Turning now to FIGS. **10-13**, in the illustrated example, the cartridge body **1710** is formed with a centrally disposed raised electrode pad **1720**. As can be most particularly seen in FIG. **6**, the elongate slot **1712** extends through the center of the electrode pad **1720** and serves to divide the pad **1720** into a left pad segment **1720**L and a right pad segment **1720**R. A right flexible circuit assembly **1730**R is attached to the right pad segment **1720**R and a left flexible circuit assembly **1730**L is attached to the left pad segment **1720**L. In at least one arrangement for example, the right flexible circuit **1730**R comprises a plurality of electrical conductors **1732**R that may include, for example, wider electrical conductors/conductors for RF purposes and thinner electrical conductors for conventional stapling purposes that are supported or attached or embedded into a right insulator sheath/member **1734**R that is attached to the right pad **1720**R. In addition, the right flexible circuit assembly **1730**R includes a "phase one", proximal right electrode **1736**R and a "phase two" distal right electrode **1738**R. Likewise, the left flexible circuit assembly **1730**L comprises a plurality of electrical conductors **1732**L that may include, for example, wider electrical conductors/conductors for RF purposes and thinner electrical conductors for conventional stapling purposes that are supported or attached or embedded into a left insulator sheath/member **1734**L that is attached to the left pad **1720**L. In addition, the left flexible circuit assembly **1730**L includes a "phase one", proximal left electrode **1736**L and a "phase two" distal left electrode **1738**L. The left and right electrical conductors **1732**L, **1732**R are attached to a distal micro-chip **1740** mounted to the distal end portion of the cartridge body **1710**. In one arrangement, for example, each of the right and left flexible circuits **1730**R, **1730**L may have an overall width "CW" of approximately 0.025 inches and each of the electrodes **1736**R, 1736L, 1738R, 1738R has a width "EW" of approximately 0.010 inches for example. See FIG. 13. However, other widths/sizes are contemplated and may be employed in alternative aspects.

In at least one arrangement, RF energy is supplied to the surgical tool assembly 1000 by a conventional RF generator 400 through a supply lead 402. In at least one arrangement, the supply lead 402 includes a male plug assembly 406 that is configured to be plugged into corresponding female connectors 410 that are attached to a segmented RF circuit 1160 on the an onboard circuit board 1152. See FIG. 15. Such arrangement facilitates rotational travel of the shaft and end effector 1500 about the shaft axis SA relative to the tool chassis 1210 by rotating the nozzle assembly 1240 without winding up the supply lead 402 from the generator 400. An onboard on/off power switch 420 is supported on the latch assembly 1280 and tool chassis 1210 for turning the RF generator on and off. When the tool assembly 1000 is operably coupled to the handle assembly 500 or robotic system, the onboard segmented RF circuit 1160 communicates with the microprocessor 560 through the connectors 1154 and 562. As shown in FIG. 1, the handle assembly 500 may also include a display screen 430 for viewing information about the progress of sealing, stapling, knife location, status of the cartridge, tissue, temperature, etc. As can also be seen FIG. 15, the slip ring assembly 1150 interfaces with a distal connector 1162 that includes a flexible shaft circuit strip or assembly 1164 that may include a plurality of narrow electrical conductors 1166 for stapling related activities and wider electrical conductors 1168 used for RF purposes. As shown in FIGS. 14 and 15, the flexible shaft circuit strip 1164 is centrally supported between the laminated plates or bars 1322 that form the knife bar 1320. Such arrangement facilitates sufficient flexing of the knife bar 1320 and flexible shaft circuit strip 1164 during articulation of the end effector 1500 while remaining sufficiently stiff so as to enable the knife member 1330 to be distally advanced through the clamped tissue.

Turning again to FIG. 10, in at least one illustrated arrangement, the elongate channel 1602 includes a channel circuit 1670 supported in a recess 1621 that extends from the proximal end 1610 of the elongate channel 1602 to a distal location 1623 in the elongate channel bottom portion 1620. The channel circuit 1670 includes a proximal contact portion 1672 that contacts a distal contact portion 1169 of the flexible shaft circuit strip 1164 for electrical contact therewith. A distal end 1674 of the channel circuit 1670 is received within a corresponding wall recess 1625 formed in one of the channel walls 1622 and is folded over and attached to an upper edge 1627 of the channel wall 1622. A series of corresponding exposed contacts 1676 are provided in the distal end 1674 of the channel circuit 1670. As shown in FIG. 10. As can also be seen in FIG. 10, an end of a flexible cartridge circuit 1750 is attached to the distal micro-chip 1740 and is affixed to the distal end portion of the cartridge body 1710. Another end 1754 is folded over the edge of the cartridge deck surface 1711 and includes exposed contacts 1756 configured to make electrical contact with the exposed contacts 1676 of the channel circuit 1670. Thus, when the RF cartridge 1700 is installed in the elongate channel 1602, the electrodes as well as the distal micro-chip 1740 are powered and communicate with the onboard circuit board 1152 through contact between the flexible cartridge circuit 1750, the flexible channel circuit 1670, the flexible shaft circuit 1164 and the slip ring assembly 1150.

FIGS. 16A-16B is a block diagram of a control circuit 700 of the surgical instrument 10 of FIG. 1 spanning two drawing sheets according to one aspect of this disclosure. Referring primarily to FIGS. 16A-16B, a handle assembly 702 may include a motor 714 which can be controlled by a motor driver 715 and can be employed by the firing system of the surgical instrument 10. In various forms, the motor 714 may be a DC brushed driving motor having a maximum rotational speed of approximately 25,000 RPM. In other arrangements, the motor 714 may include a brushless motor, a cordless motor, a synchronous motor, a stepper motor, or any other suitable electric motor. The motor driver 715 may comprise an H-Bridge driver comprising field-effect transistors (FETs) 719, for example. The motor 714 can be powered by the power assembly 706 releasably mounted to the handle assembly 500 for supplying control power to the surgical instrument 10. The power assembly 706 may comprise a battery which may include a number of battery cells connected in series that can be used as the power source to power the surgical instrument 10. In certain circumstances, the battery cells of the power assembly 706 may be replaceable and/or rechargeable. In at least one example, the battery cells can be Lithium-Ion batteries which can be separably couplable to the power assembly 706.

The shaft assembly 704 may include a shaft assembly controller 722 which can communicate with a safety controller and power management controller 716 through an interface while the shaft assembly 704 and the power assembly 706 are coupled to the handle assembly 702. For example, the interface may comprise a first interface portion 725 which may include one or more electric connectors for coupling engagement with corresponding shaft assembly electric connectors and a second interface portion 727 which may include one or more electric connectors for coupling engagement with corresponding power assembly electric connectors to permit electrical communication between the shaft assembly controller 722 and the power management controller 716 while the shaft assembly 704 and the power assembly 706 are coupled to the handle assembly 702. One or more communication signals can be transmitted through the interface to communicate one or more of the power requirements of the attached interchangeable shaft assembly 704 to the power management controller 716. In response, the power management controller may modulate the power output of the battery of the power assembly 706, as described below in greater detail, in accordance with the power requirements of the attached shaft assembly 704. The connectors may comprise switches which can be activated after mechanical coupling engagement of the handle assembly 702 to the shaft assembly 704 and/or to the power assembly 706 to allow electrical communication between the shaft assembly controller 722 and the power management controller 716.

The interface can facilitate transmission of the one or more communication signals between the power management controller 716 and the shaft assembly controller 722 by routing such communication signals through a main controller 717 residing in the handle assembly 702, for example. In other circumstances, the interface can facilitate a direct line of communication between the power management controller 716 and the shaft assembly controller 722 through the handle assembly 702 while the shaft assembly 704 and the power assembly 706 are coupled to the handle assembly 702.

The main controller 717 may be any single core or multicore processor such as those known under the trade name ARM Cortex by Texas Instruments. In one aspect, the main controller 717 may be an LM4F230H5QR ARM Cortex-M4F Processor Core, available from Texas Instruments, for example, comprising on-chip memory of 256 KB single-cycle flash memory, or other non-volatile memory, up to 40 MHz, a prefetch buffer to improve performance above 40 MHz, a 32 KB single-cycle serial random access memory (SRAM), internal read-only memory (ROM) loaded with StellarisWare® software, 2 KB electrically erasable programmable read-only memory (EEPROM), one or more pulse width modulation (PWM) modules, one or more quadrature encoder inputs (QEI) analog, one or more 12-bit Analog-to-Digital Converters (ADC) with 12 analog input channels, details of which are available for the product datasheet.

The safety controller may be a safety controller platform comprising two controller-based families such as TMS570 and RM4x known under the trade name Hercules ARM Cortex R4, also by Texas Instruments. The safety controller may be configured specifically for IEC 61508 and ISO 26262 safety critical applications, among others, to provide advanced integrated safety features while delivering scalable performance, connectivity, and memory options.

The power assembly **706** may include a power management circuit which may comprise the power management controller **716**, a power modulator **738**, and a current sense circuit **736**. The power management circuit can be configured to modulate power output of the battery based on the power requirements of the shaft assembly **704** while the shaft assembly **704** and the power assembly **706** are coupled to the handle assembly **702**. The power management controller **716** can be programmed to control the power modulator **738** of the power output of the power assembly **706** and the current sense circuit **736** can be employed to monitor power output of the power assembly **706** to provide feedback to the power management controller **716** about the power output of the battery so that the power management controller **716** may adjust the power output of the power assembly **706** to maintain a desired output. The power management controller **716** and/or the shaft assembly controller **722** each may comprise one or more processors and/or memory units which may store a number of software modules.

The surgical instrument **10** (FIGS. **1**-**5**) may comprise an output device **742** which may include devices for providing a sensory feedback to a user. Such devices may comprise, for example, visual feedback devices (e.g., an LCD display screen, LED indicators), audio feedback devices (e.g., a speaker, a buzzer) or tactile feedback devices (e.g., haptic actuators). In certain circumstances, the output device **742** may comprise a display **743** which may be included in the handle assembly **702**. The shaft assembly controller **722** and/or the power management controller **716** can provide feedback to a user of the surgical instrument **10** through the output device **742**. The interface can be configured to connect the shaft assembly controller **722** and/or the power management controller **716** to the output device **742**. The output device **742** can instead be integrated with the power assembly **706**. In such circumstances, communication between the output device **742** and the shaft assembly controller **722** may be accomplished through the interface while the shaft assembly **704** is coupled to the handle assembly **702**.

The control circuit **700** comprises circuit segments configured to control operations of the powered surgical instrument **10**. A safety controller segment (Segment **1**) comprises a safety controller and the main controller **717** segment (Segment **2**). The safety controller and/or the main controller **717** are configured to interact with one or more additional circuit segments such as an acceleration segment, a display segment, a shaft segment, an encoder segment, a motor segment, and a power segment. Each of the circuit segments may be coupled to the safety controller and/or the main controller **717**. The main controller **717** is also coupled to a flash memory. The main controller **717** also comprises a serial communication interface. The main controller **717** comprises a plurality of inputs coupled to, for example, one or more circuit segments, a battery, and/or a plurality of switches. The segmented circuit may be implemented by any suitable circuit, such as, for example, a printed circuit board assembly (PCBA) within the powered surgical instrument **10**. It should be understood that the term processor as used herein includes any microprocessor, processors, controller, controllers, or other basic computing device that incorporates the functions of a computer's central processing unit (CPU) on an integrated circuit or at most a few integrated circuits. The main controller **717** is a multipurpose, programmable device that accepts digital data as input, processes it according to instructions stored in its memory, and provides results as output. It is an example of sequential digital logic, as it has internal memory. The control circuit **700** can be configured to implement one or more of the processes described herein.

The acceleration segment (Segment **3**) comprises an accelerometer. The accelerometer is configured to detect movement or acceleration of the powered surgical instrument **10**. Input from the accelerometer may be used to transition to and from a sleep mode, identify an orientation of the powered surgical instrument, and/or identify when the surgical instrument has been dropped. In some examples, the acceleration segment is coupled to the safety controller and/or the main controller **717**.

The display segment (Segment **4**) comprises a display connector coupled to the main controller **717**. The display connector couples the main controller **717** to a display through one or more integrated circuit drivers of the display. The integrated circuit drivers of the display may be integrated with the display and/or may be located separately from the display. The display may comprise any suitable display, such as, for example, an organic light-emitting diode (OLED) display, a liquid-crystal display (LCD), and/or any other suitable display. In some examples, the display segment is coupled to the safety controller.

The shaft segment (Segment **5**) comprises controls for an interchangeable shaft assembly **500** coupled to the surgical instrument **10** (FIGS. **1**-**5**) and/or one or more controls for an end effector **1500** coupled to the interchangeable shaft assembly **500**. The shaft segment comprises a shaft connector configured to couple the main controller **717** to a shaft PCBA. The shaft PCBA comprises a low-power microcontroller with a ferroelectric random access memory (FRAM), an articulation switch, a shaft release Hall effect switch, and a shaft PCBA EEPROM. The shaft PCBA EEPROM comprises one or more parameters, routines, and/or programs specific to the interchangeable shaft assembly **500** and/or the shaft PCBA. The shaft PCBA may be coupled to the interchangeable shaft assembly **500** and/or integral with the surgical instrument **10**. In some examples, the shaft segment comprises a second shaft EEPROM. The second shaft EEPROM comprises a plurality of algorithms, routines, parameters, and/or other data corresponding to one or more shaft assemblies **500** and/or end effectors **1500** that may be interfaced with the powered surgical instrument **10**.

The position encoder segment (Segment **6**) comprises one or more magnetic angle rotary position encoders. The one or more magnetic angle rotary position encoders are configured to identify the rotational position of the motor **714**, an interchangeable shaft assembly **500**, and/or an end effector **1500** of the surgical instrument **10** (FIGS. **1-5**). In some examples, the magnetic angle rotary position encoders may be coupled to the safety controller and/or the main controller **717**.

The motor circuit segment (Segment **7**) comprises a motor **714** configured to control movements of the powered surgical instrument **10** (FIGS. **1-5**). The motor **714** is coupled to the main microcontroller processor **717** by an H-bridge driver comprising one or more H-bridge field-effect transistors (FETs) and a motor controller. The H-bridge driver is also coupled to the safety controller. A motor current sensor is coupled in series with the motor to measure the current draw of the motor. The motor current sensor is in signal communication with the main controller **717** and/or the safety controller. In some examples, the motor **714** is coupled to a motor electromagnetic interference (EMI) filter.

The motor controller controls a first motor flag and a second motor flag to indicate the status and position of the motor **714** to the main controller **717**. The main controller **717** provides a pulse-width modulation (PWM) high signal, a PWM low signal, a direction signal, a synchronize signal, and a motor reset signal to the motor controller through a buffer. The power segment is configured to provide a segment voltage to each of the circuit segments.

The power segment (Segment **8**) comprises a battery coupled to the safety controller, the main controller **717**, and additional circuit segments. The battery is coupled to the segmented circuit by a battery connector and a current sensor. The current sensor is configured to measure the total current draw of the segmented circuit. In some examples, one or more voltage converters are configured to provide predetermined voltage values to one or more circuit segments. For example, in some examples, the segmented circuit may comprise 3.3V voltage converters and/or 5V voltage converters. A boost converter is configured to provide a boost voltage up to a predetermined amount, such as, for example, up to 13V. The boost converter is configured to provide additional voltage and/or current during power intensive operations and prevent brownout or low-power conditions.

A plurality of switches are coupled to the safety controller and/or the main controller **717**. The switches may be configured to control operations of the surgical instrument **10** (FIGS. **1-5**), of the segmented circuit, and/or indicate a status of the surgical instrument **10**. A bail-out door switch and Hall effect switch for bailout are configured to indicate the status of a bail-out door. A plurality of articulation switches, such as, for example, a left side articulation left switch, a left side articulation right switch, a left side articulation center switch, a right side articulation left switch, a right side articulation right switch, and a right side articulation center switch are configured to control articulation of an interchangeable shaft assembly **500** (FIGS. **1** and **3**) and/or the end effector **300** (FIGS. **1** and **4**). A left side reverse switch and a right side reverse switch are coupled to the main controller **717**. The left side switches comprising the left side articulation left switch, the left side articulation right switch, the left side articulation center switch, and the left side reverse switch are coupled to the main controller **717** by a left flex connector. The right side switches comprising the right side articulation left switch, the right side articulation right switch, the right side articulation center switch, and the right side reverse switch are coupled to the main controller **717** by a right flex connector. A firing switch, a clamp release switch, and a shaft engaged switch are coupled to the main controller **717**.

Any suitable mechanical, electromechanical, or solid state switches may be employed to implement the plurality of switches, in any combination. For example, the switches may be limit switches operated by the motion of components associated with the surgical instrument **10** (FIGS. **1-5**) or the presence of an object. Such switches may be employed to control various functions associated with the surgical instrument **10**. A limit switch is an electromechanical device that consists of an actuator mechanically linked to a set of contacts. When an object comes into contact with the actuator, the device operates the contacts to make or break an electrical connection. Limit switches are used in a variety of applications and environments because of their ruggedness, ease of installation, and reliability of operation. They can determine the presence or absence, passing, positioning, and end of travel of an object. In other implementations, the switches may be solid state switches that operate under the influence of a magnetic field such as Hall-effect devices, magneto-resistive (MR) devices, giant magneto-resistive (GMR) devices, magnetometers, among others. In other implementations, the switches may be solid state switches that operate under the influence of light, such as optical sensors, infrared sensors, ultraviolet sensors, among others. Still, the switches may be solid state devices such as transistors (e.g., FET, Junction-FET, metal-oxide semiconductor-FET (MOSFET), bipolar, and the like). Other switches may include electrical conductorless switches, ultrasonic switches, accelerometers, inertial sensors, among others.

FIG. **17** is another block diagram of the control circuit **700** of the surgical instrument of FIG. **1** illustrating interfaces between the handle assembly **702** and the power assembly **706** and between the handle assembly **702** and the interchangeable shaft assembly **704** according to one aspect of this disclosure. The handle assembly **702** may comprise a main controller **717**, a shaft assembly connector **726** and a power assembly connector **730**. The power assembly **706** may include a power assembly connector **732**, a power management circuit **734** that may comprise the power management controller **716**, a power modulator **738**, and a current sense circuit **736**. The shaft assembly connectors **730**, **732** form an interface **727**. The power management circuit **734** can be configured to modulate power output of the battery **707** based on the power requirements of the interchangeable shaft assembly **704** while the interchangeable shaft assembly **704** and the power assembly **706** are coupled to the handle assembly **702**. The power management controller **716** can be programmed to control the power modulator **738** of the power output of the power assembly **706** and the current sense circuit **736** can be employed to monitor power output of the power assembly **706** to provide feedback to the power management controller **716** about the power output of the battery **707** so that the power management controller **716** may adjust the power output of the power assembly **706** to maintain a desired output. The shaft assembly **704** comprises a shaft processor **719** coupled to a non-volatile memory **721** and shaft assembly connector **728** to electrically couple the shaft assembly **704** to the handle assembly **702**. The shaft assembly connectors **726**, **728** form interface **725**. The main controller **717**, the shaft processor **719**, and/or the power management controller **716** can be configured to implement one or more of the processes described herein.

The surgical instrument **10** (FIGS. **1-5**) may comprise an output device **742** to a sensory feedback to a user. Such devices may comprise visual feedback devices (e.g., an LCD display screen, LED indicators), audio feedback devices (e.g., a speaker, a buzzer), or tactile feedback devices (e.g., haptic actuators). In certain circumstances, the output device **742** may comprise a display **743** that may be included in the handle assembly **702**. The shaft assembly controller **722** and/or the power management controller **716** can provide feedback to a user of the surgical instrument **10** through the output device **742**. The interface **727** can be configured to connect the shaft assembly controller **722** and/or the power management controller **716** to the output device **742**. The output device **742** can be integrated with the power assembly **706**. Communication between the output device **742** and the shaft assembly controller **722** may be accomplished through the interface **725** while the interchangeable shaft assembly **704** is coupled to the handle assembly **702**. Having described a control circuit **700** (FIGS. **16A-16B** and **6**) for controlling the operation of the surgical instrument **10** (FIGS. **1-5**), the disclosure now turns to various configurations of the surgical instrument **10** (FIGS. **1-5**) and control circuit **700**.

FIG. **18** is a schematic diagram of a surgical instrument **600** configured to control various functions according to one aspect of this disclosure. In one aspect, the surgical instrument **600** is programmed to control distal translation of a displacement member such as the I-beam **614**. The surgical instrument **600** comprises an end effector **602** that may comprise an anvil **616**, an I-beam **614**, and a removable staple cartridge **618** which may be interchanged with an RF cartridge **609** (shown in dashed line). The end effector **602**, anvil **616**, I-beam **614**, staple cartridge **618**, and RF cartridge **609** may be configured as described herein, for example, with respect to FIGS. **1-15**. For conciseness and clarity of disclosure, several aspects of the present disclosure may be described with reference to FIG. **18**. It will be appreciated that the components shown schematically in FIG. **18** such as the control circuit **610**, sensors **638**, position sensor **634**, end effector **602**, I-beam **614**, staple cartridge **618**, RF cartridge **609**, anvil **616**, are described in connection with FIGS. **1-17** of this disclosure.

Accordingly, the components represented schematically in FIG. **18** may be readily substituted with the physical and functional equivalent components described in connection with FIGS. **1-17**. For example, in one aspect, the control circuit **610** may be implemented as the control circuit **700** shown and described in connection with FIGS. **16-17**. In one aspect, the sensors **638** may be implemented as a limit switch, electromechanical device, solid state switches, Hall-effect devices, magneto-resistive (MR) devices, giant magneto-resistive (GMR) devices, magnetometers, among others. In other implementations, the sensors **638** may be solid state switches that operate under the influence of light, such as optical sensors, infrared sensors, ultraviolet sensors, among others. Still, the switches may be solid state devices such as transistors (e.g., FET, Junction-FET, metal-oxide semiconductor-FET (MOSFET), bipolar, and the like). In other implementations, the sensors **638** may include electrical conductorless switches, ultrasonic switches, accelerometers, inertial sensors, among others. In one aspect, the position sensor **634** may be implemented as an absolute positioning system comprising a magnetic rotary absolute positioning system implemented as an AS5055EQFT single-chip magnetic rotary position sensor available from Austria Microsystems, AG. The position sensor **634** may interface with the control circuit **700** to provide an absolute positioning system. The position may include multiple Hall-effect elements located above a magnet and coupled to a CORDIC processor (for Coordinate Rotation Digital Computer), also known as the digit-by-digit method and Volder's algorithm, is provided to implement a simple and efficient algorithm to calculate hyperbolic and trigonometric functions that require only addition, subtraction, bitshift, and table lookup operations. In one aspect, the end effector **602** may be implemented as surgical end effector **1500** shown and described in connection with FIGS. **1**, **2**, and **4**. In one aspect, the I-beam **614** may be implemented as the knife member **1330** comprising a knife body **1332** that operably supports a tissue cutting blade **1334** thereon and may further include anvil engagement tabs or features **1336** and channel engagement features or a foot **1338** as shown and described in connection with FIGS. **2-4**, **8**, **11** and **14**. In one aspect, the staple cartridge **618** may be implemented as the standard (mechanical) surgical fastener cartridge **1400** shown and described in connection with FIG. **4**. In one aspect, the RF cartridge **609** may be implemented as the radio frequency (RF) cartridge **1700** shown and described in connection with FIGS. **1**, **2**, **6**, and **10-13**. In one aspect, the anvil **616** may be implemented the anvil **1810** shown and described in connection with FIGS. **1**, **2**, **4**, and **6**. These and other sensors arrangements are described in commonly owned U.S. patent application Ser. No. 15/628,175, entitled TECHNIQUES FOR ADAPTIVE CONTROL OF MOTOR VELOCITY OF A SURGICAL STAPLING AND CUTTING INSTRUMENT, which is incorporated herein by reference in its entirety, now U.S. Pat. No. 10,881,399.

The position, movement, displacement, and/or translation of a liner displacement member, such as the I-beam **614**, can be measured by an absolute positioning system, sensor arrangement, and position sensor represented as position sensor **634**. Because the I-beam **614** is coupled to the longitudinally movable drive member **540**, the position of the I-beam **614** can be determined by measuring the position of the longitudinally movable drive member **540** employing the position sensor **634**. Accordingly, in the following description, the position, displacement, and/or translation of the I-beam **614** can be achieved by the position sensor **634** as described herein. A control circuit **610**, such as the control circuit **700** described in FIGS. **16**A and **16**B, may be programmed to control the translation of the displacement member, such as the I-beam **614**, as described herein. The control circuit **610**, in some examples, may comprise one or more microcontrollers, microprocessors, or other suitable processors for executing instructions that cause the processor or processors to control the displacement member, e.g., the I-beam **614**, in the manner described. In one aspect, a timer/counter circuit **631** provides an output signal, such as elapsed time or a digital count, to the control circuit **610** to correlate the position of the I-beam **614** as determined by the position sensor **634** with the output of the timer/counter circuit **631** such that the control circuit **610** can determine the position of the I-beam **614** at a specific time (t) relative to a starting position. The timer/counter circuit **631** may be configured to measure elapsed time, count external evens, or time external events.

The control circuit **610** may generate a motor set point signal **622**. The motor set point signal **622** may be provided to a motor controller **608**. The motor controller **608** may comprise one or more circuits configured to provide a motor drive signal **624** to the motor **604** to drive the motor **604** as described herein. In some examples, the motor **604** may be a brushed DC electric motor, such as the motor **505** shown in FIG. **1**. For example, the velocity of the motor **604** may be proportional to the motor drive signal **624**. In some examples, the motor **604** may be a brushless direct current (DC) electric motor and the motor drive signal **624** may comprise a pulse-width-modulated (PWM) signal provided to one or more stator windings of the motor **604**. Also, in some examples, the motor controller **608** may be omitted and the control circuit **610** may generate the motor drive signal **624** directly.

The motor **604** may receive power from an energy source **612**. The energy source **612** may be or include a battery, a super capacitor, or any other suitable energy source **612**. The motor **604** may be mechanically coupled to the I-beam **614** via a transmission **606**. The transmission **606** may include one or more gears or other linkage components to couple the motor **604** to the I-beam **614**. A position sensor **634** may sense a position of the I-beam **614**. The position sensor **634** may be or include any type of sensor that is capable of generating position data that indicates a position of the I-beam **614**. In some examples, the position sensor **634** may include an encoder configured to provide a series of pulses to the control circuit **610** as the I-beam **614** translates distally and proximally. The control circuit **610** may track the pulses to determine the position of the I-beam **614**. Other suitable position sensor may be used, including, for example, a proximity sensor. Other types of position sensors may provide other signals indicating motion of the I-beam **614**. Also, in some examples, the position sensor **634** may be omitted. Where the motor **604** is a stepper motor, the control circuit **610** may track the position of the I-beam **614** by aggregating the number and direction of steps that the motor **604** has been instructed to execute. The position sensor **634** may be located in the end effector **602** or at any other portion of the instrument.

The control circuit **610** may be in communication with one or more sensors **638**. The sensors **638** may be positioned on the end effector **602** and adapted to operate with the surgical instrument **600** to measure the various derived parameters such as gap distance versus time, tissue compression versus time, and anvil strain versus time. The sensors **638** may comprise a magnetic sensor, a magnetic field sensor, a strain gauge, a pressure sensor, a force sensor, an inductive sensor such as an eddy current sensor, a resistive sensor, a capacitive sensor, an optical sensor, and/or any other suitable sensor for measuring one or more parameters of the end effector **602**. The sensors **638** may include one or more sensors.

The one or more sensors **638** may comprise a strain gauge, such as a micro-strain gauge, configured to measure the magnitude of the strain in the anvil **616** during a clamped condition. The strain gauge provides an electrical signal whose amplitude varies with the magnitude of the strain. The sensors **638** may comprise a pressure sensor configured to detect a pressure generated by the presence of compressed tissue between the anvil **616** and the staple cartridge **618**. The sensors **638** may be configured to detect impedance of a tissue section located between the anvil **616** and the staple cartridge **618** that is indicative of the thickness and/or fullness of tissue located therebetween.

The sensors **638** may be configured to measure forces exerted on the anvil **616** by the closure drive system. For example, one or more sensors **638** can be at an interaction point between the closure tube **1910** (FIGS. **1-4**) and the anvil **616** to detect the closure forces applied by the closure tube **1910** to the anvil **616**. The forces exerted on the anvil **616** can be representative of the tissue compression experienced by the tissue section captured between the anvil **616** and the staple cartridge **618**. The one or more sensors **638** can be positioned at various interaction points along the closure drive system to detect the closure forces applied to the anvil **616** by the closure drive system. The one or more sensors **638** may be sampled in real time during a clamping operation by a processor as described in FIGS. **16**A-**16**B. The control circuit **610** receives real-time sample measurements to provide analyze time based information and assess, in real time, closure forces applied to the anvil **616**.

A current sensor **636** can be employed to measure the current drawn by the motor **604**. The force required to advance the I-beam **614** corresponds to the current drawn by the motor **604**. The force is converted to a digital signal and provided to the control circuit **610**.

The RF energy source **400** is coupled to the end effector **602** and is applied to the RF cartridge **609** when the RF cartridge **609** is loaded in the end effector **602** in place of the staple cartridge **618**. The control circuit **610** controls the delivery of the RF energy to the RF cartridge **609**.

Electrosurgical instruments apply electrosurgical energy to seal tissue. However, at times tissue may be sealed with staples delivered by a staple cartridge and at other times the tissue may be sealed by the application of electrosurgical energy. This requires the user to inventory two separate instruments. Therefore, it would be desirable to provide an elongate shaft for use with a surgical stapler where an interchangeable RF cartridge is used in place of a staple cartridge. In situations where an interchangeable RF cartridge is used in place of a staple cartridge, the present disclosure provides various techniques for covering select surfaces with non-conductive coatings to determine the electrical path of radio frequency (RF) applied energy when the interchangeable RF cartridges is used in place of the staple cartridge.

FIG. **19** is a perspective view of a surgical system **4000**. The surgical system **4000** is similar to the motor-driven surgical system **10** in that the surgical system **4000** is configured to be used in connection with the conventional surgical stapler/fastener cartridges **1400** and the radio-frequency cartridges **1700**. However, the surgical system **4000** is different from the motor-driven surgical system **10** in that the surgical system **4000** is also configured to be used in connection with radio-frequency cartridges **4002** which are similar to but different from the radio-frequency cartridges **1700** and are described in more detail below. The surgical system **4000** is also different from the motor-driven surgical system **10** in that the surgical system **4000** includes a firing system **4004** (See FIG. **22**) which is similar to but different from the firing system **1300** of the motor driven surgical system **10** and is described in more detail below.

As shown in FIG. **19**, the surgical system **4000** includes a handle assembly **4006** and an interchangeable tool assembly **4008** coupleable to the handle assembly **4006**. The handle assembly **4006** is similar or identical to the handle assembly **500** and the interchangeable tool assembly **4008** is similar or identical to the interchangeable tool assembly **1000**. The interchangeable tool assembly **4008** includes an end effector **4010** which includes a first jaw **4012** and a second jaw **4014**. The first jaw **4012** includes an elongate channel **4016** which is configured to removably support the radio-frequency cartridge **4002**. According to various aspects, the elongate channel **4016** may also be configured to removably support the surgical stapler/fastener cartridge **1400** and the radio frequency cartridge **1700**. The second jaw **4014** includes an anvil **4018**. The end effector **4010** is similar or identical to the end effector **1500**, the first jaw **4012** is similar or identical to the first jaw **1600**, the second jaw **4014** is similar or identical to the second jaw **1800**, the elongate channel **4016** is similar or identical to the elongate channel **1602** and the anvil **4018** is similar or identical to the anvil **1810**.

FIG. **20** is a partial cross-section of the end effector **4010** of the surgical system **4000** according to various aspects, showing the interface between the radio-frequency cartridge **4002** and the anvil **4018** when the end effector **4010** in a fully closed position. For purposes of clarity, the elongate channel **4016** is not shown in FIG. **20**. The radio-frequency cartridge **4002** is similar to the radio frequency cartridge **1700** but is different in that the radio-frequency cartridge **4002** includes a cartridge deck surface **4020** which defines at least two protrusions **4022**. Although only one of the protrusions **4022** is shown in the cross-section of FIG. **20**, it will be appreciated that a first one of the protrusions **4022** is positioned on one side of a centrally disposed elongate slot **4024** of the radio-frequency cartridge **4002** and a second one of the protrusions **4022** is positioned on the opposite side of the centrally disposed elongate slot **4024** of the radio-frequency cartridge **4002** (See, e.g., FIG. **21**).

The radio-frequency cartridge **4002** is also different from the radio frequency cartridge **1700** in that the radio-frequency cartridge **4002** includes insulative sheath members **4026** which respectively define protrusions **4028** which are associated with the protrusions **4022**. Although only one of the insulative sheath members **4026** and one of the protrusions **4028** are shown in the cross-section of FIG. **20**, it will be appreciated that a first one of the insulative sheath members **4026** and a first one of the protrusions **4028** are positioned on one side of the centrally disposed elongate slot **4024** of the radio-frequency cartridge **4002**, and a second one of the insulative sheath members **4026** and a second one of the protrusions **4028** are positioned on the opposite side of the centrally disposed elongate slot **4024** of the radio-frequency cartridge **4002** (See, e.g., FIG. **21**). The protrusions **4028** are positioned between the protrusions **4022** of the cartridge deck surface **4020** and the anvil **4018** of the interchangeable tool assembly **4008**.

The radio-frequency cartridge **4002** is also different from the radio frequency cartridge **1700** in that the radio-frequency cartridge **4002** further includes flexible circuit assemblies **4030** which respectively define protrusions **4032** which are associated with the protrusions **4022** and the protrusions **4028**. Although only one of the flexible circuit assemblies **4030** and one of the protrusions **4032** are shown in the cross-section of FIG. **20**, it will be appreciated that a first one of the flexible circuit assemblies **4030** and a first one of the protrusions **4032** are positioned on one side of the centrally disposed elongate slot **4024** of the radio-frequency cartridge **4002**, and a second one of the flexible circuit assemblies **4030** and a second one of the protrusions **4032** are positioned on the opposite side of the centrally disposed elongate slot **4024** of the radio-frequency cartridge **4002** (See, e.g., FIG. **21**). The protrusions **4032** are positioned between the protrusions **4028** and the anvil **4020** of the interchangeable tool assembly **4004**. Other than the protrusions **4022**, **4028**, **4032**, the cartridge deck surface **4020** is similar to the cartridge deck surface **1711**, the insulative sheath members **4026** are similar to the insulator/sheath members **1734**, and the flexible circuit assemblies **4030** are similar to the flexible circuit assemblies **1730**.

When tissue T (FIG. **6**) is positioned between the radio-frequency cartridge **4002** and the anvil **4018**, and the anvil **4018** is moved towards the radio-frequency cartridge **4002** to clamp the tissue positioned between the radio-frequency cartridge **4002** and the anvil **4018**, the minimum gap or distance d_1 between the anvil **4018** and the radio-frequency staple cartridge **4002** proximate the distal end of the end effector **4010** is realized when the insulation material **1819** positioned on the tissue facing segments **1817** of the fastener forming undersurface **1813** of the anvil **4018** is brought into physical contact with the protrusions **4032**. Once this physical contact between the insulation material **1819** and the protrusions **4032** is established, the protrusions **4032** physically prevent (1) the anvil **4018** from being brought closer to the radio-frequency cartridge **4002** and (2) the tissue from being further compressed. The establishment of this minimum gap or distance d_1 also operates to help prevent the formation of an electrical short circuit between the radio-frequency cartridge **4002** and the anvil **4018**.

An example of an RF cartridge that routes RF energy through tissue from an electrode to an inner surface of a staple pocket is shown in FIGS. **6** and **7**. Accordingly, turning briefly to FIGS. **6** and **7**, there is shown a partial cross-sectional view of the end effector **1500** depicted in FIGS. **1-5** supporting an RF cartridge **1700** (FIGS. **10-12**), **4002** (FIGS. **19** and **21**) therein and with tissue T clamped between the cartridge **1400** (FIG. **4**) and the anvil **1810** and a partial cross-sectional view of the anvil **1810**. In the example illustrated in FIGS. **6** and **7**, the anvil **1810** comprises non-conductive masking except in pockets **1814** such that all of the surfaces not for staple formation are masked off and coated with a non-conductive electrically insulative material **1819** creating a varying return path surface containing dimples and extension minimizing the charring and tissue sticking experienced by flat opposed electrodes. As shown in FIG. **6**, in at least one form, the anvil **1810** includes an anvil body portion **1812** that is fabricated from an electrically conductive metal material for example and has a staple forming undersurface **1813** that has a series of fastener forming pockets **1814** formed therein on each side of a centrally disposed anvil slot **1815** that is configured to slidably accommodate the knife member **1330** (FIGS. **2-4**, **22**) therein. The anvil slot **1815** opens into an upper opening **1816** that extends longitudinally through the anvil body to accommodate the anvil engagement features **1336** (FIG. **4**) on the knife member **1330** during firing. When a conventional mechanical surgical staple/fastener cartridge **1400** (FIG. **4**) is installed in the elongate channel **1602** (FIG. **4**), the staples/fasteners are driven into forming contact with the corresponding fastener forming pockets **1814**. The anvil body **1812** may have an opening in the upper portion thereof to facilitate ease of installation for example. An anvil cap **1818** may be inserted therein and welded to the anvil body **1812** to enclose the opening and improve the overall stiffness of the anvil body **1812**. As shown in FIG. **7**, to facilitate use of the end effector **1500** (FIGS. **1** and **2**) in connection with RF cartridges **1700**, **4002** the tissue facing segments **1817** of the fastener forming undersurface **1813** may have electrically insulative material **1819** thereon. Accordingly, the features described in reference to FIGS. **6** and **7** can be applied to the end effector **4010** (FIGS. **19** and **21**) and the RF cartridge **4002** (FIGS. **19-21**).

FIG. **21** is a partial perspective view of the radio-frequency cartridge **4002** supported by the elongate channel **4016** according to various aspects. As described above, the radio-frequency cartridge **4002** includes flexible circuit assemblies **4030** and protrusions **4032** on each side of the centrally disposed elongate slot **4024**. For purposes of clarity, the insulative sheath members **4026** are not shown in FIG. **21**. Additionally, it will be appreciated that the protrusions **4022**, **4028** are hidden from view in FIG. **21**.

FIG. **22** is an exploded perspective assembly view of portions of the handle assembly **4006** and the interchangeable tool assembly **4008** according to various aspects. The handle assembly **4006** is similar or identical to the handle assembly **500**. The interchangeable tool assembly **4008** is similar to the interchangeable tool assembly **1000**, but is different in that the portion of the firing system **4004** associated with the interchangeable tool assembly **4008** is different from the portion of the firing system **1300** associated with the interchangeable tool system **1000**. The portion of the firing system **4004** associated with the handle assembly **4006** is similar or identical to the portion of the firing system **1300** associated with the handle assembly **500**. The portion of the firing system **4004** associated with the handle assembly **4006** includes a firing drive system **4034** which includes a longitudinal drive member **4036**. The longitudinal drive member **4036** has a rack of teeth **4038** formed thereon and has an attachment cradle **4040** on its distal end. The firing drive system **4034**, the longitudinal drive member **4036**, the rack of teeth **4038** and the attachment cradle **4040** are similar or identical to the firing drive system **530**, the longitudinal drive member **540**, the rack of teeth **542** and the attachment cradle **544** of the firing system **1300**.

The portion of the firing system **4004** associated with the interchangeable tool assembly **4008** includes a nozzle assembly **4042**, an intermediate firing shaft portion **4044**, a firing shaft attachment lug **4046**, a knife bar **4043**, a firing member/knife member **4050** and a proximal closure tube **4054** which are similar or identical to the nozzle assembly **1240**, the intermediate firing shaft portion **1310**, the firing shaft attachment lug **1314**, the knife bar **1320**, the firing member/knife member **1330** and the proximal closure tube **1910**. However, the portion of the firing system **4004** associated with the interchangeable tool assembly **4008** is different from the portion of the firing system **1300** associated with the interchangeable tool assembly **1000** in that the portion of the firing system **4004** associated with the interchangeable tool assembly **4008** further includes an electrically insulative material **4056** (an electrically non-conductive material) which operates to prevent radio-frequency energy from inadvertently passing from the portion of the firing system **4004** associated with the interchangeable tool assembly **4008** to the handle assembly **4006**. In situations where radio-frequency energy is applied to the surgical instrument **4000**, the firing member/knife member **4050** may conduct radio-frequency energy. Without the electrically insulative material **4056**, the firing member/knife member **4050** may inadvertently conduct radio-frequency energy through the knife bar **4043**, through the intermediate firing shaft portion **4044** and/or through the firing shaft attachment lug **4046** to the portion of the firing system **4004** associated with the handle assembly **4006**.

According to various aspects, the electrically insulative material **4056** is a coating which covers the firing shaft attachment lug **4046**. When the firing shaft attachment lug **4046** is seated into the attachment cradle **4040** within the handle assembly **4006**, electrically insulative material **4056** operates to electrically isolate the longitudinal drive member **4036** of the firing drive system **4034** and the handle assembly **4006** from the interchangeable tool assembly **4008**. In other words, the longitudinal drive member **4036** and the handle assembly **4006** are protected from receiving inadvertent radio-frequency energy from the interchangeable tool assembly **4008**. According to other aspects, the electrically insulative material **4056** may also cover other portions of the firing system **4004** to electrically isolate the longitudinal drive member **4036** and the handle assembly **4006** from the interchangeable tool assembly **4008**. For example, the electrically insulative material **4056** may also cover other portions of a proximal end **4058** of intermediate firing shaft portion **4044**. Thus, by selectively covering various portions of the firing system **4004** associated with the interchangeable tool assembly **4008** with the electrically insulative material **4056**, the conductive path of radio-frequency energy can be designed to electrically isolate the handle assembly **4006** from the interchangeable tool assembly **4008** for instances where the radio-frequency cartridge **1700** or the radio-frequency cartridge **4002** is being utilized with the surgical system **4000**.

Aspects of the surgical instrument may be practiced without the specific details disclosed herein. Some aspects have been shown as block diagrams rather than detail. Parts of this disclosure may be presented in terms of instructions that operate on data stored in a computer memory. Generally, aspects described herein which can be implemented, individually and/or collectively, by a wide range of hardware, software, firmware, or any combination thereof can be viewed as being composed of various types of "electrical circuitry." Consequently, "electrical circuitry" includes electrical circuitry having at least one discrete electrical circuit, electrical circuitry having at least one integrated circuit, electrical circuitry having at least one application specific integrated circuit, electrical circuitry forming a general purpose computing device configured by a computer program (e.g., a general purpose computer or processor configured by a computer program, which at least partially carries out processes and/or devices described herein), electrical circuitry forming a memory device (e.g., forms of random access memory), and/or electrical circuitry forming a communications device (e.g., a modem, communications switch, or optical-electrical equipment). These aspects may be implemented in analog or digital form, or combinations thereof.

The foregoing description has set forth aspects of devices and/or processes via the use of block diagrams, flowcharts, and/or examples, which may contain one or more functions and/or operation. Each function and/or operation within such block diagrams, flowcharts, or examples can be implemented, individually and/or collectively, by a wide range of hardware, software, firmware, or virtually any combination thereof. In one aspect, several portions of the subject matter described herein may be implemented via Application Specific Integrated Circuits (ASICs), Field Programmable Gate Arrays (FPGAs), digital signal processors (DSPs), Programmable Logic Devices (PLDs), circuits, registers and/or software components, e.g., programs, subroutines, logic and/or combinations of hardware and software components, logic gates, or other integrated formats. Some aspects disclosed herein, in whole or in part, can be equivalently implemented in integrated circuits, as one or more computer programs running on one or more computers (e.g., as one or more programs running on one or more computer systems), as one or more programs running on one or more processors (e.g., as one or more programs running on one or more microprocessors), as firmware, or as virtually any combination thereof, and that designing the circuitry and/or writing the code for the software and or firmware would be well within the skill of one of skill in the art in light of this disclosure.

The mechanisms of the disclosed subject matter are capable of being distributed as a program product in a variety of forms, and that an illustrative aspect of the subject matter described herein applies regardless of the particular type of signal bearing medium used to actually carry out the distribution. Examples of a signal bearing medium include the following: a recordable type medium such as a floppy disk, a hard disk drive, a Compact Disc (CD), a Digital Video Disk (DVD), a digital tape, a computer memory, etc.; and a transmission type medium such as a digital and/or an analog communication medium (e.g., a fiber optic cable, a waveguide, a electrical conductord communications link, a electrical conductorless communication link (e.g., transmitter, receiver, transmission logic, reception logic, etc.).

The foregoing description of these aspects has been presented for purposes of illustration and description. It is not intended to be exhaustive or limiting to the precise form disclosed. Modifications or variations are possible in light of the above teachings. These aspects were chosen and described in order to illustrate principles and practical application to thereby enable one of ordinary skill in the art to utilize the aspects and with modifications as are suited to the particular use contemplated. It is intended that the claims submitted herewith define the overall scope.

Various aspects of the subject matter described herein are set out in the following numbered examples:

Example 1. An interchangeable tool assembly, comprising: a first jaw configured to support a staple cartridge during a first time period and a radio-frequency cartridge during a second time period; a second jaw coupled to the first jaw, wherein a surface of the second jaw defines a plurality of staple forming pockets configured to form staples driven from the staple cartridge; and an electrically insulative material covering segments of the surface of the second jaw other than the staple forming pockets, wherein the staple forming pockets define at least one return path for radio-frequency energy delivered by the radio-frequency cartridge.

Example 2. The interchangeable tool assembly of Example 1, wherein the interchangeable tool assembly is configured to be releasably coupleable to a handle assembly, and wherein at least one component positioned within the interchangeable tool assembly comprises electrical insulation to electrically insulate the handle assembly from inadvertent radio-frequency energy from the interchangeable tool assembly.

Example 3. The interchangeable tool assembly of one or more of Example 1 through Example 2, wherein the interchangeable tool assembly is configured to be releasably coupleable to a handle assembly, and wherein at least one component positioned within the interchangeable tool assembly comprises electrical insulation to electrically insulate the handle assembly from inadvertent radio-frequency energy from the interchangeable tool assembly.

Example 4. The interchangeable tool assembly of one or more of Example 1 through Example 3, wherein the plurality of staple forming pockets comprise: a first plurality of staple forming pockets positioned to a first side of a centrally disposed anvil slot; and a second plurality of staple forming pockets positioned to a second side of the centrally disposed anvil slot.

Example 5. The interchangeable tool assembly of one or more of Example 1 through Example 4, wherein the plurality of staple forming pockets provide for a plurality of different return paths for radio-frequency energy delivered by the radio-frequency cartridge.

Example 6. The interchangeable tool assembly of one or more of Example 1 through Example 5, wherein the segments of the surface of the second jaw face the first jaw.

Example 7. The interchangeable tool assembly of one or more of Example 1 through Example 6, further comprising a firing system positioned within the interchangeable tool assembly, wherein the firing system is configured to couple to a handle assembly, wherein the firing system is electrically insulated to electrically insulate the handle assembly from inadvertent radio-frequency energy.

Example 8. The interchangeable tool assembly of one or more of Example 1 through Example 7, further comprising a staple cartridge.

Example 9. The interchangeable tool assembly of one or more of Example 1 through Example 8, wherein the surgical system further comprises the radio-frequency cartridge.

Example 10. The interchangeable tool assembly of Example 9, wherein the radio-frequency cartridge comprises at least two protrusions which collectively provide for a minimum gap distance between the first and second jaws.

Example 11. A surgical tool assembly, comprising: an elongate channel configured to support a staple cartridge during a first time period and a radio-frequency cartridge during a second time period; and an anvil coupled to the elongate channel, wherein the anvil comprises: a surface which faces the elongate channel and defines a plurality of staple forming pockets configured to form staples driven from the staple cartridge; and an electrically insulative material which covers segments of the surface of the second jaw, wherein the plurality of staple forming pockets provide for a plurality of different return paths for radio-frequency energy delivered by the radio-frequency cartridge.

Example 12. The surgical tool assembly of Example 11, wherein the elongate channel and the anvil collectively form an end effector.

Example 13. The surgical tool assembly of one or more of Example 11 through Example 12, wherein the plurality of staple forming pockets comprise: a first plurality of staple forming pockets positioned to a first side of a centrally disposed anvil slot; and a second plurality of staple forming pockets positioned to a second side of the centrally disposed anvil slot.

Example 14. The surgical tool assembly of one or more of Example 11 through Example 13, wherein the segments of the surface of the second jaw are other than the staple forming pockets.

Example 15. The surgical tool assembly of one or more of Example 11 through Example 14, wherein the surgical tool assembly further comprises the staple cartridge.

Example 16. The surgical tool assembly of one or more of Example 11 through Example 15, wherein the surgical tool assembly further comprises the radio-frequency cartridge.

Example 17. The surgical tool assembly of Example 16, wherein the radio-frequency cartridge comprises at least two protrusions which collectively provide for a minimum gap distance between the elongate channel and the anvil.

Example 18. An interchangeable tool assembly, comprising: an end effector configured to releasably couple to a shaft assembly, wherein the end effector comprises: an elongate channel configured to support a staple cartridge during a first time period and a radio-frequency cartridge during a second time period; and an anvil coupled to the elongate channel, wherein the anvil comprises an electrically insulative material and defines a plurality of different return paths for radio frequency energy delivered by the radio-frequency cartridge.

Example 19. The interchangeable tool assembly of Example 18, wherein the electrically insulative material faces the elongate channel.

Example 20. The interchangeable tool assembly of one or more of Example 18 through Example 19, further comprising the radio-frequency cartridge.

The invention claimed is:

1. An interchangeable tool assembly configured to be releasably coupleable to a handle assembly comprising a drive system, the interchangeable tool assembly comprising:

a first jaw configured to support a staple cartridge during a first time period and a radio-frequency cartridge during a second time period, wherein the first jaw defines an elongate channel defining a recess and configured to accommodate the staple cartridge and the radio-frequency cartridge, wherein the elongate channel comprises a flexible channel circuit positioned within the recess and configured to power the radio-frequency cartridge when the radio-frequency cartridge is installed in the elongate channel, wherein the flexible channel circuit comprises an exposed contact that extends out of the recess and is folded over and directly attached to an upper edge of the elongate channel;

a second jaw coupled to the first jaw, wherein the second jaw comprises an outer tissue contacting surface and a plurality of staple forming pockets configured to form staples driven from the staple cartridge, wherein each staple forming pocket of the plurality of staple forming pockets comprises an inner staple forming surface;

a first electrically insulative material covering segments of the outer tissue contacting surface of the second jaw outside the staple forming pockets, wherein the inner staple forming surface of at least one of the staple forming pockets is electrically conductive and defines a return path for radio-frequency energy delivered by the radio-frequency cartridge;

a shaft member configured to be moved axially within the interchangeable tool assembly, the shaft member comprising an attachment portion, the attachment portion configured to engage the drive system of the handle assembly; and

a second electrically insulative material covering the attachment portion, the second electrically insulative material configured to electrically insulate the interchangeable tool assembly from the handle assembly.

2. The interchangeable tool assembly of claim **1**, wherein the plurality of staple forming pockets comprise:

a first plurality of staple forming pockets positioned to a first side of a centrally disposed anvil slot; and

a second plurality of staple forming pockets positioned to a second side of the centrally disposed anvil slot.

3. The interchangeable tool assembly of claim **1**, wherein the segments of the outer tissue contacting surface of the second jaw face the first jaw.

4. The interchangeable tool assembly of claim **1**, further comprising the staple cartridge.

5. The interchangeable tool assembly of claim **1**, further comprising the radio-frequency cartridge.

6. The interchangeable tool assembly of claim **5**, wherein the radio-frequency cartridge comprises at least two protrusions which collectively provide for a minimum gap distance between the first and second jaws.

7. A surgical tool assembly configured to be releasably coupleable to a handle assembly comprising a drive system, the surgical tool assembly comprising:

an elongate channel configured to support a staple cartridge during a first time period and a radio-frequency cartridge during a second time period, wherein the elongate channel defines a recess, wherein a flexible channel circuit is positioned within the recess and comprises an exposed contact that extends out of the recess and is folded over and directly attached to an upper edge of the elongate channel, and wherein the flexible channel circuit is configured to power the radio-frequency cartridge when the radio-frequency cartridge is supported by the elongate channel and in electrical communication with the exposed contact;

an anvil coupled to the elongate channel, wherein the anvil comprises:

an outer tissue contacting surface which faces the elongate channel;

a plurality of staple forming pockets configured to form staples driven from the staple cartridge, wherein each staple forming pocket of the plurality of staple forming pockets comprises an inner staple forming surface; and

a first electrically insulative material which covers segments of the outer tissue contacting surface of the anvil outside the staple forming pockets, wherein the inner staple forming surfaces are electrically conductive and provide for a plurality of different return paths for radio-frequency energy delivered by the radio-frequency cartridge;

a shaft member configured to be moved axially within the surgical tool assembly, the shaft member comprising an attachment portion, the attachment portion configured to engage the drive system of the handle assembly; and

a second electrically insulative material covering the attachment portion, the second electrically insulative material configured to electrically insulate the surgical tool assembly from the handle assembly.

8. The surgical tool assembly of claim **7**, wherein the elongate channel and the anvil collectively form an end effector.

9. The surgical tool assembly of claim **7**, wherein the plurality of staple forming pockets comprise:

a first plurality of staple forming pockets positioned to a first side of a centrally disposed anvil slot; and

a second plurality of staple forming pockets positioned to a second side of the centrally disposed anvil slot.

10. The surgical tool assembly of claim **7**, wherein the surgical tool assembly further comprises the staple cartridge.

11. The surgical tool assembly of claim **7**, wherein the surgical tool assembly further comprises the radio-frequency cartridge.

12. The surgical tool assembly of claim **11**, wherein the radio-frequency cartridge comprises at least two protrusions which collectively provide for a minimum gap distance between the elongate channel and the anvil.

13. An interchangeable tool assembly configured to be releasably coupleable to a handle assembly comprising a drive system, the interchangeable tool assembly comprising:

a circuit board;

an end effector configured to releasably couple to a shaft assembly, wherein the end effector comprises:

an elongate channel configured to support a staple cartridge during a first time period and a radio-frequency cartridge during a second time period, wherein the elongate channel comprises a flexible channel circuit configured to electrically couple the radio-frequency cartridge to the circuit board when the radio-frequency cartridge is supported by the elongate channel; and

an anvil coupled to the elongate channel, wherein the anvil comprises an outer surface that faces the elongate channel, an inner surface that does not face the elongate channel, and a first electrically insulative material that covers at least a portion of the outer surface of the anvil, wherein the inner surface is electrically conductive and defines a plurality of different return paths for radio-frequency energy delivered by the radio-frequency cartridge;

a shaft member configured to be moved axially within the interchangeable tool assembly to actuate the end effector, the shaft member comprising an attachment portion, the attachment portion configured to engage the drive system of the handle assembly; and

a second electrically insulative material covering the attachment portion, the second electrically insulative material configured to electrically insulate the interchangeable tool assembly from the handle assembly,

wherein the elongate channel defines a recess, wherein a majority of the flexible channel circuit is positioned within the recess, and wherein the flexible channel circuit comprises an exposed contact that extends out of the recess and is folded over and directly attached to an upper edge of the elongate channel.

14. The interchangeable tool assembly of claim **13**, further comprising the radio-frequency cartridge.

15. The interchangeable tool assembly of claim **13**, wherein the circuit board comprises a radio-frequency circuit, and wherein the flexible channel circuit is configured to electrically couple the radio-frequency cartridge to the radio-frequency circuit when the radio-frequency cartridge is supported by the elongate channel.

16. The interchangeable tool assembly of claim **13**, further comprising the radio-frequency cartridge, wherein the radio-frequency cartridge comprises a cartridge body comprising an electrode pad defining an elongate slot, wherein the elongate slot divides the electrode pad into a first pad segment and a second pad segment.

17. The interchangeable tool assembly of claim **16**, wherein a first flexible circuit assembly is attached to the first pad segment, wherein a second flexible circuit assembly is attached to the second pad segment.

18. The interchangeable tool assembly of claim **17**, wherein the first flexible circuit assembly comprises a first electrode and a second electrode configured for different phases of operation, and wherein the first flexible circuit assembly comprises a circuit width that is greater than an electrode width of the first electrode and the second electrode.

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